AD-A062 472 OKLAHOMA STATE UNIV STILLWATER ELECTRONICS LAB F/G 4/1
ROCKET INSTRUMENTATION SUPPORT SERVICES.(U)
AUG 78 R F BUCK, R M FIKE, C M GWINN F19628-75-C-0084

UNCLASSIFIED AFGL-TR-78-0207 NL

1 OF 3
AD
A062472

AFGL-TR-78-0207

ROCKET INSTRUMENTATION SUPPORT SERVICES

R. F. Buck, R. M. Fike, and C. M. Gwinn
Electronics Laboratory - D.E.T.A.
Office of Engineering Research
Oklahoma State University
Stillwater, Oklahoma 74074

31 August 1978

Final Report for Period 1 February 1975 - 31 July 1978

Approved for public release; distribution unlimited.

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

19

1. REPORT NUMBER 18 AFGL-TR-78-0207

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER 9

4. TITLE (and Subtitle) 6 ROCKET INSTRUMENTATION SUPPORT SERVICES.

5. TYPE OF REPORT & PERIOD COVERED Final Report - 1 Feb[redacted]975-31 Jul[redacted]78

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s) 10 Richard Michael Claude [redacted] F. Buck, R. [redacted] Fike [redacted] M. Gwinn

8. CONTRACT OR GRANT NUMBER(s) 15 F19628-75-C-0084

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Electronics Laboratory - D.E.T.A.
Oklahoma State University
Stillwater, Oklahoma 74074

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
~~62101F~~
16 7659[redacted] 17 01

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Geophysics Laboratory
Hanscom AFB, Massachusetts 01731
Monitor/Charles H. Reynolds/LCS

12. REPORT DATE 11 31 Aug[redacted]978

13. NUMBER OF PAGES 197

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 197p.

15. SECURITY CLASS. (of this report) Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --------------

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

----

18. SUPPLEMENTARY NOTES

----

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Instrumentation, Telemetry, Ground Support Equipment, Autotrack Antenna, Trajectory Determination, PCM Encoders, PCM Decoders

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the services supplied to the Air Force Geophysics Laboratories in support of the upper air research program. Personnel and equipment were supplied at a number of launch sites. Descriptions of airborne payload equipment and special ground support equipment are presented. Airborne equipment included telemetry and related apparatus, including both analog and digital systems. Ground support equipment included autotrack and manual antennas, trajectory determination systems, and PCM decoding systems.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

404 050 78 12 18 131 Gw

SUMMARY

Engineering and support services were supplied to the Air Force Geophysical Laboratory for a period of 42 months, in an ongoing program of rocket instrumentation for upper atmosphere research. This report documents the background and history for this program, then details the services which were supplied. The services included coordination meetings to define specific objectives and technical requirements, followed by development and construction of apparatus needed to meet the requirements. Each such item was then tested to insure compliance with the specified requirements, after which assistance was provided in installation, test, and actual launch of the equipment aboard the vehicle carrying the completed payload. Both airborne and ground elements of the instrumentation were operated during this program, and data received during the flight was received and recorded as a part of the services provided.

Equipment was provided for a total of 33 instrumented payloads during this program. Launch support was also provided in connection with the flight of 62 different payloads from eight different launch sites.

Specialized ground support equipment was also provided as required during this program. Details of the design and construction of many of these items have also been documented. This equipment has included S-band receiving antennas, both manual and with autotrack capability, and auxiliary equipment which was provided to permit trajectory determination through measurements of the slant range, combined with angular position data derived from the autotrack antenna pointing system, then processed to derive the desired trajectory elements.

Other special equipment developed in the course of this work has included a relatively large number of items for use in digital PCM telemetry applications. Circuit and constructional details for several of these devices are provided. PCM equipment was provided both in the form of special encoders for transmission of serial data from complex sources, and also for terminal use in decoding the data after transmission. Several of the systems so provided had unique requirements, in which digital and analog inputs were combined in accomplishing the required serial transmission.

Developmental activities directed toward future potential application to this continuing program are also described. These activities were also conducted for both airborne and ground applications, and will be continued under a following contract.

ACKNOWLEDGMENT

The work discussed within this report has been sponsored by the Aerospace Instrumentation Division of the Air Force Geophysics Laboratory. Special gratitude is expressed to Mr. Charles H. Reynolds of the Research Probe Instrumentation Branch, who has served as Contract Monitor throughout the period reported herein. He has consistently granted us his insight concerning future developments, directed developmental activities toward practical objectives, and encouraged pursuit of state-of-the-art approaches to the support desired.

Our thanks are also due the many unnamed personnel from both the Research Probe Instrumentation Branch and the Research Probe Flight Branch who have lent their assistance and cooperation to our staff; without their efforts in maintaining the flow of timely technical coordination required by this complex program, great difficulty would have existed in meeting schedule deadlines which required interrelationships between our staff and other participants.

We also extend our appreciation to all individuals from other agencies involved with this overall program, for the many valuable contributions and suggestions offered in the laboratory and in the field during the forty-two months of work which is reported herein. The remarkable attitude of team spirit which transcended individual professional affiliations was of significant importance in the success of the instrumentation program.

LIST OF CONTRIBUTORS

The following staff members (listed alphabetically) from the Oklahoma State University Laboratory (Division of Engineering, Technology, and Architecture) have contributed to the work described in this report:

Robert S. Anderson
Richard F. Buck
Joseph M. Cooper
A. Dale Costner
Doyle K. Craft
Donald G. Dale
R. Michael Fike
Tom B. Gwin
Claude M. Gwinn
Darrell L. Haston
Timothy W. Herron
Leslie D. Hoy
Lorene Kinnamon
Scott Laverde
Martha M. Luckey
Paul R. Park
Kenneth R. Pilcher
L. Orion Schmitt
Marta Schneider
Leonard J. Skach
Jackie W. Spears
Rosalee I. Stafford
Barbara L. Tyler
Jerry R. Waughtal
Joe B. Zinn

TABLE OF CONTENTS

ROCKET INSTRUMENTATION SUPPORT SERVICES

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

The work reported herein, performed under contract F19628-75-C-0084, has been primarily instrumentation and engineering services which were provided to the Air Force Geophysics Laboratories by the Oklahoma State University Electronics Laboratory. The services cover a wide variety of activities. All are directed towards supporting a program of upper air research, which involves rocket and balloon vehicles as carriers for instruments to perform measurements of the parameters of the earth and its atmosphere. The services include development of special apparatus, both for inclusion in airborne payloads and as special ground support equipment, compatible with and facilitating interpretation of data from these payloads. In addition to development of apparatus, electronic supporting systems are designed and assembled from a combination of commercially procured and locally fabricated items. Each of these support systems is tailored to provide the required functions for the scientific instrument with which it is to be flown. These services are primarily provided through the facilities at the base laboratory in Stillwater, Oklahoma. Additional services are supplied at other sites as required, in the form of manpower and equipment for needed tests and operation of the instruments and payload as they are tested and flown. The field services customarily include both "integration testing" of the system to be flown (wherein the instrument is mated with the supporting electronics and all other portions of the apparatus, to verify proper interconnections and function) and later, through the launch sequence, include the operation prior to flight and the reception and recording of data from the payload during the actual mission.

1.1 Previous Related Work

The services provided to AFGL by the Electronics Laboratory have carried on through a series of contracts, beginning in 1947 with the first efforts to explore space through use of captured V-2 rockets at the White Sands Proving Grounds. The initial work was associated with tracking and providing an element of command control to the airborne system used with these early liquid-fuel rockets, under contract W28-099ac-376. A continuous succession of similar supporting service contracts has followed, maintaining continuity in this effort and permitting flexibility by constant adaptation of previous experience to update the support supplied for both airborne and ground elements of the overall program. In the body of the report which follows, specific

reference will be made to sponsoring contracts which represent the source of some projects which still continue. Services have expanded with time and changes in the state of the art; the most recent work is the direct outgrowth of a series of related contracts which began in 1970 (under F19628-70-C-0147) and continued (roughly in 3-year increments) under F19628-72-C-0139, F19628-72-C-0172, and F19628-75-C-0084, the present contract.

1.2 Contract History

In response to a Request for Proposal, number F19628-75-R-0037, in July 1974, the Oklahoma State University Electronics Laboratory submitted a proposal for three years of support services, outlining the work planned during this period, the expertise and capability of the crew available, and the types of airborne and ground equipment which were anticipated throughout the course of this effort. As a result of this proposal, Basic Contract F19628-75-C-0084 was executed on 3 January 1975, with a commencement date of 1 February 1975 and an anticipated completion date of 31 January 1978. Although the total estimated cost for these services was $1,320,433, the contract was established on an incrementally funded basis with initial funding of $160,651 available to provide initial services through the period of 30 June 1975. A series of consecutive amendments (numbers P0001 through P00017) have since been executed, mostly for the purpose of adding incremental funding to cover further extensions of the work program initially proposed. (Some amendments were strictly administrative in nature, dealing with changes in accounting data, administrative instructions, or changes in applicable specifications.) Amendment P00016 effectively modernized the form of the contract and the supporting documentation through Federal requirements. Delivery of services was extended through 31 July 1978, with the final reproducible report requirement extended to 10 October 1978. Total funding for this entire period of services was established at $1,391,133, to cover 41 months of services and the additional time required for preparation of the final report to document those services.

1.3 Contract Objectives

The objectives of the work and services supplied under this contract were defined in the contract under Part II, Section F, the Statement of Work. This Statement of Work called for Oklahoma State University Electronics Laboratory to supply the necessary personnel, facilities, services, and material to

accomplish the tasks described below, as quoted from the referenced section of the contractual document:

"Line Item 0001 - Provide engineering and technical support for instrumenting thirty (30) research rockets, ground instrumentation support for sixty (60) research rockets, instrumentation and tests concerning telemetry, tracking and associated instrumentation systems and continuation of the development of a system to provide trajectory information through the telemetry system.

Sub-Line Item 0001AA - Instrument thirty (30) research rockets for data transmission and reception and trajectory determination as follows:

a. Modify, fabricate, test and install rocket equipment.

b. Perform integration tests at AFCRL, to insure compatibility with the experiment and with simulated range instrumentation.

c. Support environmental tests at AFCRL.

d. Support tests at rocket range during preparation and launch. Rocket launches will be at sites to be designated by the Contracting Officer and will include but not necessarily be limited to Churchill Research Range, Canada; Poker Flat Research Range, Alaska; White Sands Missile Range, N.M.; NASA Wallops Island, VA; and Vandenberg AFB, California.

Sub-Line Item 0001AB - Provide services toward operating ground based instrumentation systems in support of sixty (60) rocket launches at rocket ranges to be designated by the Contracting Officer as listed in Sub-Line Item 0001AA (d) as follows:

a. Maintain and operate ground based data reception and recording equipment.

b. Devise improvements to existing equipment to meet special requirements.

Sub-Line Item 0001AC - Conduct studies, investigations and tests concerning telemetry and associated rocket instrumentation systems leading to the design of sub-miniature, light weight, rugged, reliable components.

Sub-Line Item 0001AD - Continue the development of the tracking through telemetry system initiated under Contract F19628-72-C-0139 (TRATEL System). Incorporate the techniques and circuits devised thus far into a portable system suitable for use at remote launch sites.

Line Item 0002 - Data in accordance with Contract Data Requirements List, DD Form 1423 (Revised), dated 77SEP08 attached hereto and made a part hereof."

1.4 Related Efforts, Other AFGL Contracts

Work performed under this contract was a logical extension of the services of similar nature supplied to AFGL under preceding contract F19628-72-C-0139. (The period of work for this contract was 1 February 1972 through 31 March 1975.) In the initial phases of this contract, there was also a considerable overlap with AFGL contract F19628-72-C-0172, under which support services were provided for an Infrared Rocket Payload Program. (These special services were provided through the period of 1 May 1972 through 31 January 1976.) Under this overlapping contract, much special purpose ground support equipment was developed and this special equipment, later transferred to this contract, was then modified, updated and further developed. In particular, automatic tracking S-band antenna equipment, trajectory determination systems, and both pulse amplitude modulated (PAM) and pulse code modulated (PCM) telemetry apparatus was developed for specific applications. These applications were not limited to the Infrared Rocket Payload Program and have consequently been carried forward to the more general program of Upper Air Research.

At the present time, similar support services are being continued under AFGL contract F19628-78-C-0033. Work under this new contract commenced on 1 March 1978, and will extend for a period of three additional years. The objectives are quite similar and will include further development and extended use of equipment which was initiated as a development under the contract reported herein.

1.5 Special Comment, Reconstruction Activities

Early on the morning of 31 May 1977, lightning struck the Electronics Laboratory facility in Stillwater, Oklahoma, causing a disastrous fire which totally destroyed the physical facility in which this work was carried on. Although much of the equipment (both government-owned and University-owned) which was necessary for continuation of this effort was either totally destroyed or seriously damaged, the major portion of the documentation of the work underway was removed from the building intact during the fire, and a significant portion of the special electronics equipment was also salvaged from the fire. Approximately 65% of the airborne and ground support equipment, as well as some of the general laboratory and machine shop equipment, were moved to temporary quarters on the main campus of Oklahoma State University and an intensive effort devoted to reestablishment of the Electronics

Laboratory capability. A new and larger building has been planned and construction has been started; in the meantime, a delay of approximately 90 days occurred to the major work effort under this contract while equipment salvaged from the fire was refurbished, reconditioned, or rebuilt as required to meet scheduled support activities. Recovery from the losses of the fire have been largely responsible for the extension in time of performance under contract F19628-75-C-0084. The major loss was caused by damage to the three automatic S-band tracking antenna systems and the destruction of the associated trajectory determination systems; this has now been compensated for and all three tracking systems have been completely rebuilt and placed in functional condition. In rebuilding, circuitry was updated in accord with developments which had been made in the latter portion of this contract. Three additional trajectory determination systems have also been built up since the fire, thus restoring the Laboratory's capability for support of remote launch activities. Almost all of the specialized airborne apparatus described in section 4.0 of this report was salvaged intact and (after retest and recertification) found usable in the program, as originally planned.

2.0 TRAVEL AND RELATED SUPPORT ACTIVITIES

The nature of the engineering services supplied under this contract has been such as to require work at locations other than the home laboratory in Stillwater, Oklahoma. A total of 935 man days of effort on the part of staff members from the Electronics Laboratory was required for field support activities at other sites in the course of this contract. Services supplied away from the Stillwater laboratory may be categorized as falling into four specific types of activities:

(1) Technical coordination, to define specific program objective schedules.

(2) Testing and verification of the operation of electronic equipment planned for future flight activities.

(3) Supporting services at the launch site, during the actual launch sequence for an instrumentation payload.

(4) Tests and evaluation of developmental apparatus, performed under field service conditions.

2.1 Coordination and Planning Meetings

As a general rule, technical coordination meetings have been scheduled

so as to occur in conjunction with other scheduled test activities at the AFGL facility in Massachusetts. This provides an obvious economy in the use of travel funds, and also permits maximum use of the technical personnel and equipment involved. Personnel from the Oklahoma State University Electronics Laboratory and other participating agencies which are to be involved in the overall program are frequently brought together in the natural course of such tests; the majority of the necessary technical coordination is thus accomplished as a byproduct of the preprogram tests. Many other coordination meetings have been held at the Stillwater facility, in order that participants might view equipment under development or a demonstration of recently completed equipment in conjunction with the agenda for the meeting. Occasionally technical coordination is conducted at other sites for a similar reason: facilities scheduled for use at some later date may be inspected in conjunction with the coordination, or apparatus which is under development for an associated program may more conveniently be viewed and demonstrated at the particular location where it is being developed.

2.1.1 A total of sixteen (16) coordination meetings were held at the Stillwater, Oklahoma Laboratory during the period of this contract. These were scheduled for planning, review of status, and technical definition of forthcoming requirements; the laboratory staff participated as required.

Mr. C. H. Reynolds/LCS of AFGL visited the Electronics Laboratory for such meetings on a number of dates. On 15 May 1975, the activities proposed for the remainder of calendar year 1975 were discussed and our progress reviewed in the developmental areas of this contract.

J. R. Griffin/LCS also attended similar meetings with the engineering staff of the Laboratory in the period of 20-22 August 1975. These meetings were specifically concerned with discussions of the characteristics of the TRATEL automatic tracking system and the TRADAT trajectory determination system which was developed for use in this program. The meetings also covered preliminary discussions of the MSMP payload design objectives.

Mr. Griffin and Wm. Miller of LCS visited the Laboratory again in the period of 1-3 October 1975 to discuss the specific technical objectives to be met by the Electronics Laboratory in developing a special PCM encoding system for use with the MSMP payload.

Mr. Miller/LCS again attended meetings at the Electronics Laboratory on

27 January 1976, for additional technical coordination on related aspects of the MSMP instrument and program.

C. H. Reynolds and J. D. Griffin of AFGL attended a series of technical conferences and coordination meetings on 28 and 29 April 1976. During this series of meetings the forthcoming schedule for field support activities were reviewed in detail and technical details for both MSMP and BAMM projects were discussed with the staff who were involved in development of special apparatus. These meetings also included demonstrations by the Electronics Laboratory of the newly completed "Minitracker" system, for automatic tracking of S-band signals, and the portable equipment was accepted for delivery after satisfactory proof of performance.

C. H. Reynolds/LCS returned to Stillwater on 8 July 1976, both for technical coordination and to familiarize himself with the reorganization of the Electronics Laboratory. Effective 1 July 1976 the previous University agency of the Research Foundation was dissolved, and the Electronics Laboratory reassigned to the Office of Engineering Research, under the Division of Engineering, Technology, and Architecture (DETA) within the University administrative structure. Mr. Martial Davoust of ONR also attended the same meeting, in his capacity of Contract Administrator under Amendment P0007 to the contract.

J. R. Griffin/LCS again attended meetings at the Stillwater facility on 5 August 1976 for additional discussions on the objectives and requirements for both the MSMP and BAMM programs. Modifications to the Minitracker system were also demonstrated, and plans for deployment of this system for field support were made.

C. H. Reynolds/LCS again attended meetings on 26 August 1976, in which progress to date was reviewed and requirements for future performance were discussed. Specific reference was made to support action to be taken in the coming fiscal year, with reallocation of effort in accordance with budgets and funding availability.

J. E. Palinski and K. R. Walker, both of LC group at AFGL, attended the Oklahoma State University facility for the period of 3 through 11 November 1976. The primary purpose for this series of meetings was review and coordination of requirements for modification of a special instrumentation support van belonging to AFGL. The staff of the Electronics Laboratory also conducted a short training course in the methods of set-up and operation of the

TRATEL/TRADAT system of tracking and trajectory determination, for their use in establishing a similar mode of operation with AFGL tracking system. The AFGL instrumentation van was left at the Stillwater site for extensive modification, including the addition of the TRADAT system of trajectory determination to the available Canoga tracker which formed a portion of the LC support capability.

Mr. Reynolds again visited the Electronics Laboratory on 19 November 1976 in order to discuss changes in the launch schedule and associated support requirements for the forthcoming 6-month period. The desired directions for future developmental work in conjunction with ranging and trajectory determination were discussed in a second series of technical conferences.

F. H. Cooke and J. W. Rogers of OPR/AFGL attended a series of meetings concerning the BAMM program requirements on 1 and 2 December 1976. Discussions were held concerning operational aspects of the planned support program, as well as the data reduction techniques to be employed with digital data from a special PCM encoder being developed by the Electronics Laboratory for use on the BAMM payloads.

Mr. Reynolds/AFGL and Mr. Davoust (of the ONR office in Austin, Texas) attended meetings at the Electronics Laboratory on 15 February 1977. Both administrative and technical matters were discussed in a joint meeting in which an attempt was made to find the proper division of administrative action between the Air Force agency at L. G. Hanscom Field and the Resident Representative Office of the ONR in Austin, Texas, to whom much contract administration had been delegated. Following the joint administrative meeting, technical conferences were held between the Electronics Laboratory staff and Mr. Reynolds, discussing the unique support requirements expected to arise within the next quarter for the BAMM and MSMP projects.

Mr. Griffin returned to the laboratory on 11 April 1977 for a special technical coordination meeting concerning BAMM program support requirements in the proposed field operation.

Mr. C. H. Reynolds again visited the Electronics Laboratory on 14 April 1977, for the purpose of revising the launch schedule and associated support requirements. The discussion also included plans for developmental activities under the Stillwater program and redefined our long range objectives.

Immediately after the fire which destroyed the previous laboratory facility on West 6th Street, some special meetings were called to assess the

damage and discuss the impact of the fire upon future programs. Mr. Griffin of AFGL inspected the temporary facility which had been established on the main campus, viewed the site of the fire, and assisted in an initial survey of fire losses. In a series of meetings during the period 6-9 June 1977, emergency procedures were discussed and the restoration of support capability discussed in some detail. A major impact of the fire was on the SAMSO-supported portion of the Laboratory's work. Consequently, Maj. W. G. Weppner of the SAMSO offices attended a meeting on 8 June 1977 to assess the impact of the fire on the BAMM program. As a result of conferences concerning the status of the equipment recovered and the repairs required to restore the desired support capability, a decision was made to postpone the first BAMM test flight for a period of 90 days while the laboratory rebuilt the TRATEL and TRADAT systems which were required for the field mission.

Mr. C. H. Reynolds/LCS/AFGL also visited the temporary Laboratory during the period 6-8 July 1977, in order to review the situation after 30 days of recovery operations. Mr. Martial Davoust of the ONR office in Austin, Texas attended these same meetings, wherein procedures to be followed in relieving the University of accountability for lost government equipment and the channels to be followed in requesting a fund authorization for restoration of some of the losses were discussed. An inventory check of salvaged accountable property was also made by Mr. Davoust for a preliminary loss report.

Mr. Reynolds returned to the Electronics Laboratory on 8 November 1977 for a series of administrative and technical conferences. University plans for construction of a new laboratory, and the floor layout and organization of the proposed facility were inspected, after which a series of administrative and technical conferences were held. The remainder of the support program anticipated under this contract was reviewed in some detail and plans made for a contractual extension in time in order to complete work delayed by the fire. The forthcoming schedule of launch activity and ground support requirements for the next 6-month period were reviewed and discussions held concerning the delayed developmental activities, which were to be resumed under the following contract. Special emphasis was placed in these discussions on the SAMSO-sponsored programs for the BAMM and MSMP vehicles.

Mr. Jack Griffin returned to the Electronics Laboratory for a series of meetings on 14 and 15 December 1977. Although primary coordination was concerned with the BAMM program, secondary topics of discussion concerned future

deployment of automatic tracking equipment and the ground support equipment requirements for BAMM, MSMP, and ZIP programs. A lengthy review of the field activities which had been involved in support of the first BAMM flight was held as a critique, for use in further scheduled activities of a similar nature.

A final coordination meeting was held in Stillwater to review the transfer of activities from this contract to the succeeding contract, F19628-78-C-0033. Mr. C. H. Reynolds/LCS met with both administrative and technical staff members on 12 and 13 July 1978; Mr. M. W. Davoust/ONR also attended the meeting. After review of the status of developmental activities and support shedules, the desired disposition of residual property by transfer to the following contract was arranged.

2.1.2 In addition to those coordination meetings conducted in conjunction with integration tests, some specific coordination meetings were also called at the AFGL facility.

C. M. Gwinn and J. B. Zinn of Oklahoma State University attended meetings at the AFGL facility on 15 through 17 October 1975, when all members of the MSMP team were convened for preliminary planning and discussion of program objectives and division of work amongst the various participants.

C. M. Gwinn was also called to a special BAMM coordination meeting, for a Program Review in the period of 30 August through 3 September 1976. Detailed technical discussions were held with the concerned parties, concerning the requirements for the special PCM encoder to be developed by Oklahoma State University and also for the purpose of discussing the physical facilities to be provided for field support during the launch missions under this program.

Mr. Gwinn and Mr. Zinn returned to the AFGL facility for an MSMP participant meeting and another Program Review in the period of 11 through 14 January 1977. Modifications required for the OSU-developed encoder for this program were established as a result of changes in the technical requirements which were discussed at this meeting. Some additional features for outside procurement activities (required for auxiliary apparatus to be used in this program) were also discussed.

J. B. Zinn attended another scheduled meeting for the MSMP program at the AFGL facility in the period of 23 through 26 January 1978. Mr. R. M. Fike of our organization also attended the same meeting, in which a discussion of the

failure of the first MSMP vehicle and its impact upon the remainder of the program was discussed. Mr. Fike provided a critique on the adequacy of the tracking equipment employed, whereas Mr. Zinn offered his expertise with regard to the telemetry system and encoder.

Mr. R. F. Buck attended coordination meetings from 12 through 14 February 1978 at the AFGL facility, in which the conclusion of the contract activities was discussed and planning made for the transition to the following contract, F19628-78-C-0033.

2.1.3 Coordination activities were also conducted at a few other sites in the course of this project.

Mr. R. M. Fike of the Laboratory staff attended a special seminar on microprocessor techniques in Dallas, Texas on 9 and 10 February 1976. Information of use in adapting the KIM-I microprocessor to real time data reduction with the OSU trajectory data system was the primary interest in this meeting.

Mr. R. M. Fike and R. F. Buck also attended the 22nd International Instrumentation Symposium in San Diego, California on 24 through 28 May 1976. Again the primary topic of interest was the special section devoted to microprocessor techniques and state-of-the-art advances in instrumentation.

Mr. D. L. Haston and Mr. R. M. Fike of the laboratory staff attended a special meeting in Enterprise, Alabama at the facility of Enterprise Electronics on 1 through 2 March 1976. This meeting was scheduled for the purpose of viewing an antenna pedestal and other components adaptable to the development of the OSU Minitracker. Demonstrations were performed and the equipment accepted as satisfactory for incorporation in the OSU design.

Mr. Zinn of our organization, accompanied by J. R. Griffin of AFGL, made an extensive survey of potential sites for support of the BAMM launch program in the vicinity of Fallon, Nevada and Chico, California. Meetings were conducted with personnel at both sites to discuss the requirements for physical space, electrical power, and the logistics of supporting remote tracking stations for the BAMM payload in this general launch area. The meetings were conducted in the period of 11 through 16 April 1977.

Mr. J. B. Zinn also attended planning meetings for the IRBS rocket series at the Space Vector Corporation facility in Canoga Park, California in the period of 9 through 12 January 1978. The group which met at this facility reviewed the objectives of the program, with particular reference to the data

requirements to be processed by the PCM encoder being developed at Oklahoma State University (OSU) for use on this series of payloads.

2.1.4 In addition to the technical conferences discussed in this section, some purely administrative conferences were also held at the Stillwater facility. The majority of these meetings involved personnel from the Office of Naval Research (ONR), to whom administrative responsibility for this contract was delegated in 1975.

Martial W. Davoust of the ONR office visited OSU on 9 July 1975 for routine checks of inventory accountability for Air Force property used in support of this contract.

Mr. Davoust returned for a similar inspection visit on 7 and 8 July 1976. In addition to inventory checks and review of accountability records, he also discussed with University personnel the proper channels to be followed as a result of the transfer of administrative responsibility from PPR to his office, under amendment P0007 to this contract.

J. E. Bates (of the same ONR office in Austin) visited the Laboratory on 12 May 1977 to conduct a survey of all government property in our custody and verify our inventory control and accountability records.

Mr. Davoust of the ONR office returned to the Laboratory on 4 October 1977 to review records of property, with particular reference to correcting property records in such a manner as to relieve the University of accountability on the items lost in the Laboratory fire of May 1977. Instructions were also provided on proper procedures desired in establishing inventory records for the equipment procured in replacement of the fire losses.

Mr. M. S. Baile of HEW visited the Laboratory on 22 February 1978 in order to review methods of cost accounting and budget preparation utilized here in support of government contracts. In essence, a preaudit of costs for the forthcoming period was conducted to verify the acceptability of budgets then in preparation for the following contract.

Mr. Davoust of ONR returned for another review of property records on 19 April 1978. Again the primary concern was with proper disposition of equipment lost in the fire, and proper authorization for replacement equipment as a result of such losses.

Mr. Davoust again returned to survey University accountability records on property under this contract on 13 July 1978. Instructions were offered

for the proper method of preparing a termination inventory at the conclusion of this contract.

2.2 Integration Test Activities

Travel was required to the AFGL facility on a number of occasions, in order to provide both manpower and equipment in support of integration and prelaunch test activities for several programs. During these tests, those portions of the payload equipment which had been fabricated and tested at OSU facility were mated to and tested with remaining portions of the payload which were supplied by the organizations. (This is done in order to verify suitability of all equipment, and assure that equipment is flightworthy and operational.) In most of the cases, these tests include simulated flight routines, vibration, and sometimes temperature and environmental checks. They also provide an opportunity to define the field procedures and support requirements for the launch operation which will follow. In the course of this contract, 13 such trips requiring a total expenditure of 72 man days of effort were required. This portion of our support may be divided into four types of integration tests: those performed in support of the falling sphere program, the mass-spectrometer program, the BAMM program, and the MSMP program.

2.2.1 Integration tests for falling sphere instruments (under the ABRES program) required tests at the AFGL facility in the period of 16 through 21 June 1975, again in the period of 16 through 18 June 1976, and once more during the interval of 26 through 28 July 1976. Twelve man days of support were provided for a total of three different sphere payloads: A09.406-1, A10.406-2, A11.408-1. All three of these payloads were later launched either from the Western Test Range or the Kwajalein Missile Range.

2.2.2 Mass-spectrometer payloads of several types were the subject of integration tests on a number of different occasions. Integration tests were performed for A10.304-1 and -2 in the interval of 14 through 19 July 1975. A similar series of tests were required for A09.403-1 and -2 in the interval of 8 through 12 December 1975. A following sequence of mass-spectrometer payloads, A10.403-4 and A10.001-2, were subjected to integration testing in the period of 8 through 13 March 1976. The special neutral mass-spectrometer payload of A10.705-1 was run through an integration test, and special mass-spectrometer calibrations with the PCM subsystem were interfaced with PDP-11 equipment in the interval of 8 through 12 August 1977.

Twenty-seven man days of effort were required in support of integration tests for the mass-spectrometer program.

2.2.3 The MSMP program has required a great deal of travel. First formal integration test activities were performed specifically in connection with the 27 through 30 June 1976 trip, in which the first version of the airborne MSMP coder was delivered and subjected to qualifying tests at the AFGL facility. This encoder was later launched on A24.609.1 as the TEM-1 payload, but the equipment was lost due to failure of the recovery system. This has necessitated preparation of a second unit under this contract, and further testing of the replacement unit.

2.2.4 Delivery and integration testing of the OSU-built 2-channel high speed PCM encoder for the BAMM payload has required a total of four different trips to the AFGL facility. Initial delivery and certification testing under simulated altitude conditions were performed in the period of 3 through 9 August 1977. As more portions of the payload became available, additional integration tests were performed in the period of 23 August through 3 September 1977, 21 through 24 September 1977, and 20 through 26 February 1978. Twenty-nine man days of effort were devoted to special tests of the BAMM encoder at the AFGL facility.

2.3 Launch Support Activities

Extensive field support services are supplied in connection with actual launch support missions. These missions were conducted at a total of eight different launch sites in the course of this contract. Personnel and equipment from this organization were required for a series of necessary functional and operational test procedures, including prelaunch assembly and checks, turn-on and verification of payload status during the launch sequence, and operation of ground receiving equipment for data reception and recording throughout the mission. Much of the support equipment provided in conjunction with this activity will be described elsewhere in this report, and was developed and constructed in the laboratory for this specific purpose. A total of 62 different payloads were supported in the course of this program. Twenty-one flights occurred from the Poker Flats Research Range in Alaska (PFRR), eleven flights from the Churchill Research Range in Canada (CRR), eleven from the White Sands Missile Range, New Mexico (WSMR), two from the Western Test Range in California (WTR), three from the Kwajalein Missile Range in the

Marshall Islands (KMR) six from Eglin AFB in Florida (EAFG), one from Chico, California, one from Holloman AFB, New Mexico, and one from the NASA facility at Wallops Island, Virginia. A number of additional rockets were supported at various launch sites to the point where local conditions forced cancellation prior to successful launch; activities for these aborted missions were, in general, associated with field support of other successful rounds in the same series. Seven hundred fourteen man days of activity were devoted to this phase of our activities; a detailed listing of the exact services and tests is impractical and has been documented for each occasion in the formal trip report provided at the conclusion of the launch effort. Six types of basic program were supported in the field under this contract, and form a convenient breakout of the type of effort involved.

2.3.1 One series of projects involved several sequences of rocket firings in an Arctic environment, in order to achieve synoptic and correlated data on a number of parameters. These included the ICE CAP, POLAR CAP ABSORPTION, and PARADISE AEOLUS series.

The first such effort was associated with the Paradise Aeolus series of 9 Paiute-Tomahawk rockets, launched from the Churchill Research Range in Manitoba, Canada. Eighty-three man days of support were provided for this mission, and the series of rockets fired included three of the spectrometer payloads, A10.403-1,-2, and -3. Support activities covered the period of 25 March through 26 April 1975. The TRATEL tracking system was successfully deployed in the Arctic environment for automatic tracking of this series of rockets.

The next synoptic series was again polar in nature, for the ICE CAP 76 program at PFRR near Fairbanks, Alaska. The mission extended throughout the period from 9 February through 3 April 1976. Six of the original nine payloads scheduled were fired, prior to a temporary close-down of activities on 13 March 1976. One round in this series (A10.507-1) included a falling sphere experiment of the type reported elsewhere.

ICE CAP 76 launch activities were resumed on 25 March 1976 and a seventh rocket of the series, IC630.02-1A, was successfully launched on this second occasion. The remaining two payloads were rescheduled for launch when the PFRR facility reopened the following year.

Another series of polar launches occurred at PFRR for a series of DNA rockets. Because of failure to achieve the desired auroral conditions, this

operation required two separate trips. The first field support was supplied in the period 24 October through 20 November 1977; the crew returned to the Alaskan site on 20 February 1978 and successfully concluded this mission on 15 March 1978. Some support during this mission was supplied from this contract in conjunction with other related support provided to the Utah State University through a separate arrangement with the OSU Electronics Laboratory. These ancillary support services were provided under Defense Nuclear Agency contract DNA 001-76-C-0256. Direct Air Force support to the mission under this contract required 52 man days of effort. Four payloads were successfully launched.

An earlier and similar synoptic series of launch support activities, although not Arctic in nature, occurred at the WSMR, with a series of six Astrobee D vehicles supported in the period of 27 November through 5 December 1975. Although only 16 man days of effort were directly chargeable to this particular mission, the overlap with an Aerobee 350 rocket (A35.191-1) which was supported under AFGL contract F19628-72-C-0172 resulted in a larger OSU party than usual being in the field. Activities for this series have been reported previously (Ref. 1, Section 2.4.2). This series of launches also formed a convenient series for tests and evaluation of recently developed TRADAT trajectory system, which was deployed and used both for the Aerobee 350 and the entire Astrobee series of vehicles as a source of secondary data acquisition for recording of telemetry data by means of the TRATEL autotrack antenna while evaluating the trajectory system.

2.3.2 Launch support activity for the falling sphere program also continued throughout the life of this program. In addition to the one falling sphere mentioned in connection with the ICE CAP 76A series, 47 man days of support were provided at the WTR at Vandenberg Air Force Base in connection with the launch of A10.406-2, and an additional 13 man days were provided at the same launch site in December of 1975 for the launch of A09.406-1.

Support was supplied for two more sphere payloads launched from the Kwajalein Missile Range (at the Roi Namur site, Marshall Islands) for 26 days in the interval 8 August through 2 September 1976. Rounds A11.408-1 and A11.605-1 were launched during this mission.

Two other trips were made to the same site at the KMR. The first, for 9 man days in the interval of 26 February through 6 March 1976, was made for the purpose of launching A11.712-1, but this round was subsequently cancelled

due to logistic difficulties. A reschedule occurred and a second trip was made in the period of 6 through 22 May 1976, at which time the round was successfully launched. A total of 26 man days was devoted to support of this round.

2.3.3 A number of mass-spectrometer rounds were supported in the course of this contract. In addition to the three mass-spectrometer payloads included as a portion of the Paradise Aeolus program previously mentioned, launch support was supplied at a number of different sites for other mass-spectrometer payloads.

Rounds A10.304-1 and -2 were supported at the WSMR in the period of 9 through 19 September 1975. Forty-two man days were provided in conjunction with the launch of these rounds. The OSU-developed TRATEL and TRADAT systems were deployed in conjunction with this series, and again utilized to achieve real time data for the trajectory and simultaneously to retrieve automatically data from the airborne vehicle.

Thirty-one man days of effort were required in January 1975 for the successful launch from Wallops Island test station of mass-spectrometer payload A09.402-2.

An additional 34 man days of support were provided at the CRR in Manitoba, Canada for the launch of two mass-spectrometer payloads on 26 and 29 April 1975. These rounds, A10.403-4 and A10.001-2, were tracked manually for data retrieval.

2.3.4 A single infrared payload, representing a continuation of those rockets previously supported under preceding contract F19628-72-C-0172, required 19 man days of effort at the WSMR. The Earth Limb Sensor instrument was launched on vehicle A35.191-4 during this mission on 3 August 1976.

Associated with this support was also the first operational test of the OSU-developed Minitracker system, which was sent to WSMR and operated as a test system to provide backup telemetry coverage during the launch of the above vehicle. The Minitracker was also used to successfully track NASA rocket 26.043, which was launched during the same time interval. These tests validated performance of the Minitracker system for field use, although it was not considered as prime instrumentation for support of the vehicle.

2.3.5 Although the Multi-Spectral Measurement Program (MSMP) has been a major part of the effort within the past three years, only a single round was launched in the latter portion of this contract. The first MSMP payload was launched on AIRES vehicle A24.609-1 at the WSMR in November 1977.

Twenty-eight man days of effort was supplied in field support of this launch.

2.3.6 Field support for the Balloon Airborne Mosaic Mapper program (BAMM) was also provided on two different occasions in the course of this contract.

The first series of flight tests required one hundred eleven man days of effort, and were supported from the Chico, California site by a crew of four men from the OSU laboratory. Both TRATEL and Minitracker systems were deployed for tracking the payload, and the TRADAT system was operated for trajectory data. In addition, OSU-supplied equipment for the AFGL (Canoga) tracker system and its associated ranging system were set up in a remote location for this mission. A test of the tracking system and ranging occurred on 8 October with the flight of a different balloon from the same launch site; this indicated that equipment was in proper operational condition. Damage occurred to the BAMM payload at about this same time, resulting in a delay of the test flights. The first test flight of the BAMM system occurred on 13 October 1977, but was prematurely terminated by an onboard timer. The system was recovered and repaired. On 20 October 1977 a second test launch was attempted and equipment functioned satisfactorily, but full planned altitude was not reached. Recovery was again successful and a test made prior to relaunch. Rapidly deteriorating weather finally forced cancellation of the scheduled full mission, with the operational payload.

A second series of BAMM missions was rescheduled in the spring of 1978 from the Holloman Air Development Center in New Mexico. One hundred four man days effort were required in support of this series of tests. Again both the TRATEL and Minitracker systems were utilized, together with the modified AFGL Canoga system. Although bad winds delayed operations considerably, a successful test launch of this system occurred on 24 March 1978, and served to verify the procedures planned and support capability required for launch of the special instrument. The test flight duration was approximately four hours. A considerable delay ensued for the main flight because of consistently bad wind conditions. Launch of the operational instrument finally occurred on 6 April 1978, but instrument section was lost almost immediately after lift off by a mechanical failure, and the payload was damaged by loss of the main sensing instrument. The remainder of the payload functioned properly; the command system was used to deploy the parachute and recover the remainder of the equipment, proving the equipment suitable for the planned mission.

2.4 Equipment Tests

Tests of special ground support equipment developed and constructed at OSU have continuously been carried out in conjunction with the overall support activities provided to the AFGL. As noted in conjunction with the launch support activities above, a number of specific "proof" tests were conducted in conjunction with launch support activities, with special emphasis on the performance capability of the special equipment which was built for automatic tracking of payloads in flight and for trajectory data determination from the same flights.

The original version of the automatic tracking system, TRATEL, was evaluated as well as used operationally in the Paradise Aeolus series at CRR in the spring of 1975. Satisfactory operation was achieved, but no ranging data was installed for this first series of tests.

In the fall of 1975 a series of tests were conducted with the addition of ranging capability to the tracking equipment by use of TRATEL II (supplemented by TRADAT II) systems in conjunction with the launch of Mass-spectrometer rounds. These payloads were equipped with both radar beacons and the OSU trajectory determination system, to permit correlation of data. Successful results were achieved.

The TRATEL/TRADAT system was deployed at WSMR again in November 1975 and a series of six Astrobee D payloads were equipped with ranging receivers, to permit TRADAT determination of trajectory in conjunction with the regular Astrobee D program. All six of the test rockets were launched on 2 December with varying results. Although the TRATEL system functioned properly throughout, ranging data was lost on a number of the payloads. Subsequent investigation disclosed that the ranging transmitter deviation was abnormally high and the narrow bandwidth receivers used in the Astrobee D payloads were unable to accept the wideband signal, resulting in very poor ranging reception. Partial trajectories were only obtained for three of the six rockets, but all of the desired telemetry data from the main instrumentation section was satisfactorily recovered through the TRATEL autotrack system for all six. On the following day, the tracker system (without the ranging capability) was tested again on an Aerobee 350, A35.191-1. A successful track was obtained.

The Minitracker system was also deployed at WSMR for preliminary field evaluation in the summer of 1976. (This test was scheduled because of ongoing

OSU support at the same site for the ELS payload, A35.191-4.) As a full check on the basic concept behind the Minitracker, one man was dispatched with the entire tracking system in the rear of a station wagon, to see if it would be feasible to deliver, setup, and operate this equipment with a one-man crew. The system was delivered and set up successfully on 29 July. The system proved relatively easy to set up, and several days were devoted to local checks, calibrating the Azimuth and Elevation angles and verifying the site location by survey data. On 3 August the ELS payload was successfully launched with prime telemetry coverage through normal WSMR installation. Although the Minitracker was unsuccessful at tracking the rocket through the launch tower at lift-off, the target was acquired manually and satisfactory lock to autotrack achieved at about T+25 seconds. Autotrack was continued successfully from this point until impact. (It is interesting to note that the prime support data was lost late in the flight on this mission, while the Minitracker was still successfully retrieving data. Since we had been able to make tape recordings during the Minitracker test, these data records permitted playback of data from the experiment for the missing data and verified the concept of the portable station, designed for use at launch ranges without normal support capability.)

The same Minitracker was used again on 4 August 1976 to track a launch (from a different launch site) on the NASA rocket, A26.043. Again, the track was successful. The second rocket was tracked all the way from launch, without the necessity for manual acquisition after liftoff, due to improved geometry between the tracker and the launch tower used for the second flight.

All tracking equipment was also used later in normal launch support missions; those following support missions are not classed as evaluation tests.

3.0 PAYLOAD SUPPORT SYSTEM BUILDUP

A major item of work under this contract requires the instrumentation of support systems for individual rocket payloads by supplying the necessary complement of equipment to provide adequate support for the particular scientific instrument being flown. This portion of our work is required under Subline Item 0001AA, under which we were requested to "instrument 30 research rockets for data transmission and reception and trajectory determination." Under this line item, airborne equipment was supplied in various forms for a total of 33 such rocket payloads. For 11 of this group, the entire mechanical/electrical support system (including telemetry, trajectory determination, and

all required auxiliary equipment) was fabricated, wired, and tested locally prior to integration with the remaining portion of the payload. The support sections for six additional rocket payloads were supplied under this contract, in which the mechanical portion was built and electrical portion supplied, but final systems were packaged to individual instrument requirements elsewhere by using components and structures supplied under this contract. Seventeen additional support systems were provided only as electrical portions of the support system, which were to be incorporated into other subsystems in an appropriate manner to support the remaining instruments. All of these systems were provided both through procurement from commercial sources on some necessary items, by incorporation of government-furnished property as a portion of the systems, and also by local design, test, and fabrication of special items not available through the above sources. For the systems in which the entire payload support section (including both mechanical and electrical portions) was completely designed, assembled, and tested, the types provided may be further subdivided to three discrete types of systems: Those provided in support of falling sphere experiments, those provided in support of mass-spectrometer instruments, and those provided in the form of combination telemetry and ranging subsystems for other classes of instruments.

Complete payload support systems designed and fabricated locally are generally constructed as an essentially independent section of the overall rocket payload, so designed as provide mechanical compatability with the rocket vehicle and other portions of the payload which are to be carried by the same vehicle. A typical support package of this type is shown in Figure 1. As will be noted, a cylindrical configuration is used in which a relatively thick-walled skin section serves as the main load-bearing element, with mechanical joints fore and aft detailed to fit the instrument and other portions of the payload at either end. (Each support system is designed to have both electrical and mechanical compatibility with the rocket payload for which it is to be used.) The cylindrical skin section normally carries antenna systems for both the data transmission system and the trajectory determination system. Other electronic components are mounted to an inner structure, which is suspended from the skin. This structure will carry the subsystems for the telemetry used for data transmission and whatever version of trajectory determination equipment is required. In addition, this internal structure carries the associated batteries for electrical power, suitable control relays, and auxiliary monitor

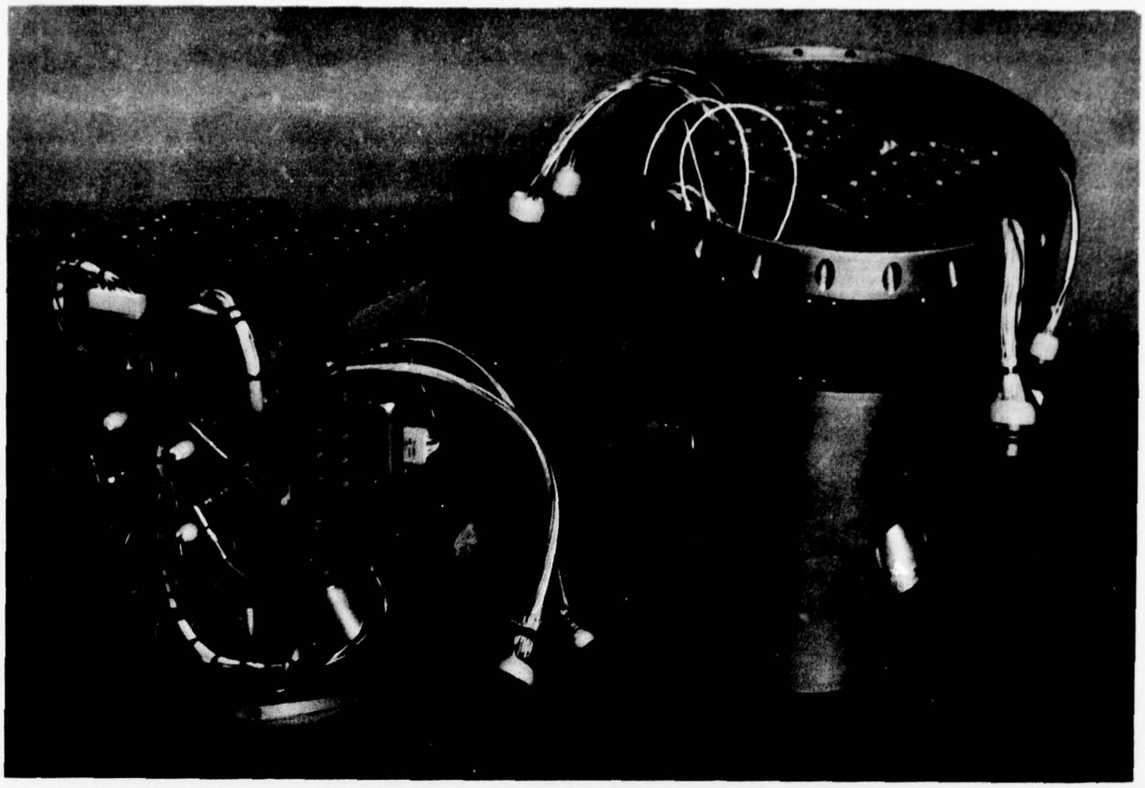


Figure 1. Cluster Ion Support System

and housekeeping performance instrumention. A quick-release umbilical connector is mounted at an angle to this outer skin and will permit operation and control through an associated console, but will automatically be stripped out at liftoff by being restrained to the launch rail. Design details in both mechanical and electrical requirements will vary for the individual payloads with which each system is to be used.

Rather than describe in great detail the individual variations of design for all rounds, the following text will present the significant features of each class of payload systems which were designed and built under this contract. One payload indicative of the general circuitry involved in each of the three classes will be described in detail; variations on this design were used for others within the same class.

3.1 Falling Sphere Experiment Support Systems

One typical class of payloads of which a number were built during the course of the contract are those special support systems built to go with the

falling sphere experiments. These payloads are to make measurements of the density of the earth's atmosphere by use of an instrument which detects deceleration, inversely proportional to the density and drag, and telemeters data back concerning this parameter. These payload support sections differ from others in that they are typically provided as a portion of the launch vehicle which carries this sphere aloft, and will remain with the payload after the sphere is ejected to obtain the desired scientific data. (The sphere contains its own instrumentation and telemetry subsystem, and is not the subject of this report; the instruments are provided external to the rocket support system.) Complete support systems were provided for a total of four sphere rounds: A09.406-1 (OSU model C38SE01); A10.406-2 (OSU model D38TE01); A08.706-1 (OSU Mod D38TE11); and A08.706.2. (This latter round is scheduled to be rebuilt to a new configuration due to design changes under a following contract, but was originally fabricated and assembled as a duplicate of the A08.706-1 round with the same model number shown above. It should also be noted that A08.706-1 and -2 were originally designed and fabricated under an earlier AFGL designation of A10.712-3 and -4, but these round numbers were changed at a later date and the A10.712-3 and -4 rounds were fired in a different configuration from payload systems fabricated elsewhere.)

3.1.1 Significant features of the sphere support systems are the requirement that the actual instrument (which is located in the forward portion of the payload and ejected in flight) must have its umbilical control system brought down through the OSU support package to a master umbilical. In addition, pyrotechnic circuitry for ejection of the nose fairing which houses the sphere, and also for ejection of the sphere instrument, are both provided as internal portions of the payload support system. Fully redundant pyrotechnic circuitry is provided for dual ejection circuits in the forward portions of the payload. Each sphere support system also includes vehicle monitors in the form of longitudinal accelerometers (to measure thrust of the motors) and a spin sensor designed to measure the spin velocity of the rocket, which is a necessary parameter for stabilization of the sphere prior to its ejection. A magnetometer is conventionally used as the spin sensor on these rounds. A multichannel FM/FM analog telemetry system is used, and the vehicle telemetry is radiated back to the ground on an S-band carrier. (The instrument data is relayed to the ground through separate transmitter within the sphere.) This vehicle telemetry is primarily for housekeeping purposes. A radar beacon is

used to provide trajectory data for the launch vehicle, and may be either C-band or S-band, depending upon available radar at the proposed launch site. Suitable battery power for operation of the telemetry and radar beacon subsystems is provided by a nickel-cadmium battery; a system of relays and monitors permits operation and control. The vehicle monitor system provides through telemetry the longitudinal acceleration, the spin rate, the condition of the battery providing prime power to the support system, the status of the flight programmers used to time the ejection sequence, a monitor of the instrument battery (within the ejectable sphere) prior to the actual moment of ejection, and monitors of the pyrotechnic firing signals to both tip eject and sphere eject circuitry. Monitors of the ejection sequence are also provided as verification of the fact that the system has ejected properly. Besides the four complete support systems described above, two additional systems were fabricated to the same electrical/mechanical design, then shipped elsewhere for installation and completion. The circuitry developed for the A08.706 series (OSU Mod D38TE11) will be described as indicative of the overall circuitry which is provided for this class of support system.

3.1.2 The telemetry subsystem in the payload support system for this round consisted of a 9-channel FM/FM analog telemetry system, in which a series of voltage-controlled oscillators are combined in a mixer amplifier, then used as modulating voltage to a radio transmitter whose signal is radioed back to the ground receiving station by an annular flush-mounted antenna, tuned to the proper frequency and provided as a portion of the mechanical structure.

The data conditioning portion of the system will be described in a later portion of this report. Analog data signals, processed to a range of from 0 to +5 volts, are fed to each of nine Vector model TS41-1 voltage-controlled oscillators. Data assignments for this round were as listed in the table at the top of the following page, and were selected to provide the desired frequency response for each data input signal.

A08.706-1 Telemetry Subsystem

IRIG Ch	Center Frequency	Data Assignment
10	5.4 KHz	Telemetry Battery Monitor
11	7.35 KHz	Timer Status Monitor
12	10.5 KHz	Sphere B+ Monitor
13	14.5 KHz	Sphere Ejection Monitor
14	22 KHz	Tip Monitor
15	30 KHz	Magnetometer (Spin Rate)
16	40 KHz	Longitudinal Acceleration
17	52.5 KHz	Squib No. 1 Monitor
18	70 KHz	Squib No. 2 Monitor

The nine oscillator frequencies, corresponding to these nine data signals, are mixed in a mixer amplifier (Vector Model TA-48) and the output (adjusted to the desired level for the proper transmitter deviation) is fed as modulation input to the associated transmitter. All nine VCO's and the mixer amplifier are mounted within a 10-position chassis mount, Vector Model M-159-MA.

The combined signals from the mixer amplifier are taken as modulation input to the associated transmitter, a Conic model CTM-402E transmitter with a carrier frequency of 2251.5 MHZ and a nominal RF power output of 2 watts. This frequency, modulated by the combined spectrum of the data channels, is then radiated to earth by means of a Guide model 5487 antenna which serves as the base of the overall structure used for a support system.

3.1.3 Trajectory determination for the vehicle is provided by a standard commercial radar beacon installed within the payload. For these payloads, the Vega Model 302C-2 beacon was used. The transponder receives interrogation from the ground on a frequency of 5800 MHz in a double-pulse interrogation code in which the two pulses are spaced 5 microseconds for proper interrogation. A reply signal, generated by the second pulse of the interrogation pair, is then retransmitted on a frequency of 5720 MHz for reception and ranging by the associated radar set. The beacon subsystem uses a pair of PSL model 7.016 bent valentine antennas, mounted in diametrically opposed locations on the outer surface of the skin of the vehicle. A suitable phasing harness is used to match each pair of antennas to the nominal impedance of 50 ohms required for this beacon.

3.1.4 Two fully redundant and completely independent pyrotechnic release systems are installed in each payload of this class. Operation of either is adequate to supply proper release of the nose tip fairings and ejection of the

instrumented sphere. The two independent pyrotechnic release systems are essentially identical, differing only in slight differences in the time at which actuation of each circuit is set to occur. In general, prime release functions are assigned pyrotechnic circuit #1 and the timing is set for the desired release. The independent system #2 is then adjusted to perform exactly the same functions, delayed approximately one second with respect to the primary system. Holex guillotine cutter squibs are used to perform the release functions; each such squib is provided with two independent ignition wires. One ignition system for each is actuated by the primary #1 squib release system, whereas the second is actuated one second later by the backup #2 system to insure that maximum reliability for firing is achieved. In addition, the squib installations themselves are redundant in that the tip release system utilizes two such squibs, but operation of either one is sufficient to release both halves of the two conical half sections which surround the sphere and serve as an aerodynamic fairing during flight. This sphere ejection system consists of a spring-loaded cradle which is equipped with a set of three more such guillotine release devices, each with two igniters, and any one of which is adequate to release the entire system and eject the scientific instrument.

Primary power for each squib system is supplied by a pack of ten Silvercell batteries, Yardney model PM-1. Redundant wiring is brought from positive and negative terminals of these squib packs to separate relay contacts, permitting the system to be switched to "arm" or "safe" at will by remote control of latching relays through the umbilical system into the rocket from the control console. Four-pole double-throw latching type relays are used, Babcock model BR23-S56. One set of relay contacts of each relay is so wired as to serve as an umbilical monitor of the state of each relay; this permits the control console indicate whether the relays are in the "safe" or "arm" mode. A second set of contacts is wired to provide a telemetry monitor of the pyrotechnic battery pack voltage when in the "arm" mode. A third set of contacts is used to arm the circuitry to the tip eject squib system, while the fourth set is utilized in a similar manner to arm the contacts to the sphere eject system. The back contacts, closed in the "safe" mode, are used as safety contacts to provide a short circuit across the pyrotechnic circuitry while in the "safe" mode, thus reducing sensitivity to stray signal pickup with the consequent hazard of premature bridge wire actuation within the squibs.

Voltage from the squib pack is taken through the "arm" contact of the associated squib relay to a safety plug, accessible through an access door in the side of the rocket payload. Normally, for ground safety, this feature is used to provide a positive safety while handling and working the payload. Mating connectors are wired in both "safe" and "arm" configurations; the "safe" plugs are installed at all times until the vehicle is armed, either for a specific circuit check or for actual launch. The "safe" plugs are provided with a set of contacts which are shorted to one another, and provide an open circuit to the firing circuit, so that all squibs are shorted regardless of the position of the timer or arm-safe relays until the arm plug is installed. The "arm" plug provides the proper distribution from timer contacts to the squibs and thus completes the firing function when installed.

The timers used for the pyrotechnic function on this rocket are Raymond model 1060-10G-90T-4PDT. Each such timer consists of a spring-wound clockwork mechanism which is wound manually through the same access door used for access to the arm/safe plugs and is cocked prior to launch. A mass-loaded ratchet mechanism, sensitive in the direction of thrust when the rocket is first fired, holds the timer in the "cocked" mode until ignition of the rocket payload occurs. Approximately 1.5 seconds after motor ignition, the clockwork mechanism will have advanced far enough to bypass this latch function and the timer proceeds through its 90 second cycle.

When the vehicle is fired, each timer starts running shortly after liftoff. Cams 1 and 2 transfer from the "cock" to the "run" mode, indicating that the timers are operating by changes in the timer status monitor. At approximately 50 seconds after liftoff, cam 3 transfers, removing the short circuit from the tip eject squib system and applying firing voltage. Approximately 10 seconds later, cam 4 transfers from the "safe" mode to the "fire" mode, applying squib voltage to the sphere eject squibs. As in the case of the arm/safe relays, back contacts of cams 3 and 4 have been wired across the squib circuit in such a manner as to provide a safety short circuit until such time as the cams are actuated and apply firing voltage to the squibs.

3.1.5 Housekeeping and monitor subsystems for these payloads are provided either through commercial sensors installed as a portion of the payload, or by processing within the associated monitor box (OSU model C38ATE12). This monitor box combines into one convenient module within the payload all the required signal conditioning circuitry.

Power from the telemetry subsystem battery at 28 volt level is fed into this monitor box to provide the input battery condition monitor to ch 10 of the VCO system. An offset zener regulator system is used by which the approximately 24 volt drop across a zener diode, 1N723A, is used to derive a signal approximately 24 volts less than the actual battery voltage. The voltage is then suitably divided to provide an output voltage in the range of 0 to 5 volts, corresponding to raw battery voltage at the T/M battery terminals of approximately 24 to 34 volt span. (Use of this system magnifies the variation by suppressing the large d.c. component which is normally present.) Use of this circuitry permits monitor of battery condition from a freshly charged state, where the output terminal voltage will be approximately 32 volts, down to a 24 volt level which is regarded as the minimum value, at which the battery should be recharged.

The same battery bus is also down-regulated by a simple zener regulator to a level of 6.2 volts through use of a series dropping resistor and 1N753A zener diode. This low voltage supply is used as input to a series of resistor dividers, provided for the purpose of monitoring the time of occurrence of various events within the payload. The same bus is dropped from 6.2 volts to a 5 volt level and applied as excitation voltage to the associated accelerometer. This accelerometer (Conrac model 24158C-10/25-50) is a mass-loaded 5000 ohm resistor, spring restrained such that the rest position (no external force applied) is approximately 1.25v above the ground reference terminal. Application of thrust from the rocket motor displaces the arm of the potentiometer toward the +5 volt end, resulting in signals greater than 1.25v. Conversely, drag forces due to deceleration will displace the arm in the opposite direction, permitting measurement of drag forces by output voltages between 0 and 1.25 volts. The output from the accelerometer is used as input to one channel of the telemetry subsystem.

Vehicle spin rate is sensed by use of a Schonstedt model RAM-5B-12V magnetometer. This device uses a sensor probe, excited in a bridge configuration by an oscillator within the magnetometer electronics. Modulation of the sensor field coils by the earth's magnetic field results in unbalance of the bridge, which is detected by the electronics and then provided as a suitable input signal for telemetry. Because these magnetometers operate at a 12 volt input potential and the primary battery power within the vehicles is nominally 28 volts, a down regulator is supplied to reduce the applied voltage to the

required 12 volt level. A Motorola regulator chip, 78M12U6, is used for this purpose and is inserted in series with the input power lead to pin 1 of the magnetometer connector.

The condition of the battery within the sphere instrument in the forward nose housing is monitored by a lead from the sphere subsystem to the monitor box and, through suitable jumper connections, to the input of another channel of the telemetry. Sphere ejection is also sensed by the monitor box by the fact that 2 pins on the sphere pullaway are jumpered together internal to the sphere; these leads are connected between a voltage dividing network and ground in such a manner as to permit a step change in the monitor voltage at the time the sphere is ejected, clearing the short circuit. Voltage for the sphere ejection monitor is provided within the monitor box, from the 6.2v regulated bus described previously.

A somewhat similar system is used to monitor the operation of the timers. As described for the pyrotechnic circuitry, one set of contacts of each timer is brought out to the telemetry monitor. These contacts are so connected and wired across a series of resistive elements which form a voltage divider across the 6.2v bus to ground. Various combinations of conditions exist in which both timers are cocked, the number one timer is running, the number two timer is running, or both are running simultaneously. Resistor values in the network are so chosen as to permit status monitors of: approximately 1 volt when both are cocked, 2 volts if the number 1 timer is in the "run" mode, 3 volts if the number 2 timer is in the "run" mode, or 4 volts if both timers are in the "run" mode simultaneously. Output from the monitor box is again fed to the associated telemetry subsystem for transmission to the ground.

The tip eject monitor system is essentially identical to that provided for the timer status monitors, in that the same voltage divider network is used across the 6.2v bus to ground. However, wiring goes to a pair of micro-switches located within the tip eject system in such a way that the larger half of the tip depresses one switch holding it closed, while the smaller half depresses the second one, holding it closed. Again, four states exist for the system: both tips on with an output voltage of 1 volt; the large tip only off, with a voltage of 2 volts; the small tip only off, where the voltage is 3 volts; or both tips off simultaneously, in which the case the voltage indication is 4 volts.

The squib monitor circuits are somewhat more elaborate and two such

circuits are provided within this payload as portions of the monitor box. In order to maintain electrical isolation between the telemetry monitor system and the actual squib firing circuit, optically-coupled devices are used for this purpose. In each such device (Monsanto Model CT-2) a light emitting diode (LED) is energized by the squib voltage within the isolated squib circuit. Light from this LED is sensed by a phototransistor within the device and used to modulate base current, thus providing an output emitter current which is modulated by the brightness of the LED, so thus is proportional to the applied voltage from squib battery pack. The isolated variable current from the phototransistor, taken through a suitable resistor to ground, serves as the input voltage source to the associated telemetry subsystem. In operation, arming of the squib relay completes the voltage circuit through a series-limiting resistor to the LED, permitting a signal to appear on the telemetry voltage bus. Parameters are so chosen as to provide a voltage of approximately 4 volts to the telemetry system when the circuit is armed. As each switch within the spring-operated timer closes, applying firing current to the associated squib release mechanisms, a momentary depression of this voltage occurs due to the surge current which flows into the bridge squib wire. This voltage fluctuation on the squib line is then translated as a variation in intensity, giving a modulated signal for the telemetry system when an impulse occurs with the firing of each squib. The amplitude of the impulse is proportional to the number of squib circuits energized and this provides a rough indication of the fact that all bridge wires are actuated by the flight timer.

The monitor box also includes some voltage divider networks, provided for the purpose of current limiting and scale setting for meters within the external console. These are used to indicate the actual voltage present within both the sphere system and the payload support system.

3.1.6 Control, monitor, and operation of each payload support system is provided by an associated console, connected to the payload through the umbilical connector. For the sphere packages, the associated control box includes both a sphere control section (utilizing 15 pins of the umbilical) and a vehicle control section (utilizing 20 other pins) within the same umbilical system.

Telemetry subsystem and beacon subsystem power control are handled through latch relays, Potter & Brumfield Model HL4102. These latch relays use a polarity-sensitive coil and so permit latch into either of two modes.

For the "off" or "test" function, this relay is energized in such a manner as to provide power within the payload from a contact, brought through the umbilical to a source of external power within the console. (This permits operation of any subsystem desired by means of an external power supply, for local tests.) Prior to flight, the relay control voltage is reversed momentarily to the coil of these latching relays, transferring the contact to the "fly" mode in which case 28.8 volt nominal power is provided from an onboard nickel cadmium battery. Identical relays are used for the telemetry subsystem and the beacon subsystem, thus permitting either or both systems to be operated in the test mode at will.

The associated nickel cadmium battery is also connected to the umbilical through a steering diode, permitting the battery to be charged through the umbilical while the payload is assembled. An internal resistor in this battery is brought through the umbilical plug to the associated control console to permit measurement of the battery voltage, either while charging or while the system is in operation.

3.2 Mass Spectrometer Support Systems

A number of payload support systems were also supplied for mass spectometer payloads within the course of this project

3.2.1 These systems differ substantially from those described above for the density experiments in several respects. No pyrotechnic release circuitry is required, since the instrument remains a portion of the rocket vehicle throughout usable flight. However, since this is the case, a more complex telemetry subsystem is required in order to accommodate the scientific information from the instrument as well as the housekeeping functions. In general, these payloads are flown with an associated attitude control system (ACS) to stabilize the instrument during the flight, and thus telemetry requirements are also complicated by the additional data channels required to monitor proper performance of the control system. Interconnecting wiring must be provided within the support system for the attitude control system and the instrument proper, which are located in separate portions of the assembled rocket payload. Because the telemetry subsystem is more complex and also carries the scientific data, provision is normally included for calibration of the telemetry system, both before flight and at intervals during flight. A radar beacon is normally installed as the trajectory subsystem for those packages. Battery

power and controls are essentially as described previously.

A total of seven complete spectrometer support systems were fabricated as mechanical and electrical subassemblies for use in this program; two additional support systems were built up to our design for mechanical and electrical portions, but assembled and tested elsewhere, providing the desired configuration for special flight installation. The rocket payloads and models involved in this project were as follows: A10.001-2 (OSU C36GA01); A10.304-1 and -2 (OSU D38ME01); A09.402-1 and -2 (OSU C36FE01); A10.403-4 (OSU C36GA01); A10.705-1 (OSU D38PE01); and the final pair under construction at the termination of this contract, A10.708-1 and -2 (OSU D38CE01). Although differences occurred with respect to the carrier frequency, the choice of the radar transponding subsystem, and the exact components selected for the individual payloads listed above, they are typified by the model D38PE01, supplied for A10.705-1.

3.2.2 The telemetry subsystem for this particular payload used a full 19 channel IRIG FM/FM analog telemetry subsystem. Each of the 19 channels consisted of a standard IRIG voltage-modulated subcarrier oscillator (SCO), whose output was frequency modulated by an input data signal in the range of 0 to +5 volts dc. The 19 individual SCO's were then mixed in a mixer amplifier and fed out as the composite modulation signal to an S-band telemetry transmitter. Signal was radiated from the subsystem to the ground by an antenna, PSL model 55.805 which was inserted in a cavity in the skin, which served as a cylindrical load-bearing structure for the overall support subsystem. As in the case of the following sphere telemetry subsystem, the telemetry channel assignments were made in accord with the frequency response requirements for each individual input data signal to be transmitted back to the ground receiving system. As a convenience in adjusting the complex of discriminators used in the ground station, the preflight calibration mode for the telemetry subsystem energized all nineteen channels simultaneously with suitable levels of calibration voltage. In actual flight, some channels were omitted from the calibration sequence to avoid interrupting data. Telemetry channel assignments were made in accord with the table on the following page.

Telemetry assignments for A10.705-1 were as follows:

IRIG Ch	Frequency	Data
1	400 Hz	Magnetometer (Spin Rate)
2	560 Hz	Mass Spectrometer (Commutated Data)
3	730 Hz	Instrument Ion Pump
4	960 Hz	Instrument High Voltage
5	1.3 KHz	Emission Regulator
6	1.7 KHz	ACS Roll (Fine)
7	2.3 KHz	ACS Roll (Coarse)
8	3.0 KHz	Longitudinal Accelerometer
9	3.9 KHz	Mass Spectrometer DC Level
10	5.4 KHz	Instrument RF Reference
11	7.35 KHz	Instrument Pressure
12	10.5 KHz	ACS Pitch Position (Fine)
13	14.5 KHz	ACS Pitch Position (Coarse)
14	22 KHz	ACS Yaw Position (Fine)
15	30 KHz	ACS Yaw Position (Coarse)
16	40 KHz	ACS Nozzle Monitor
17	52.5 KHz	PAM Commutator (Housekeeping)
18	70 KHz	Mass Spectrometer Digital Voltage
19	93 KHz	Mass Spectrometer Multiplier (Analog Output)

All nineteen SCO's were combined in the associated mixer amplifier, and the 20 modules so required were mounted in two separate OSU-built chasses because of the number being too large for a single standard mount. The main chassis (OSU C99SC03) was a design originally developed under an earlier AFGL contract (F19628-67-C-0224) and has been described in the final report to that contract (Ref. No. 2, Section 4.6.1). This design uses a dual channel MOSFET gate to switch input signals for individual SCO's between the data sources being transmitted from the payload and selected accurately-determined calibration voltages, which are substituted during the calibration process. An auxiliary chassis was also used (OSU B35AB11) to house the additional SCO's used for this particular payload. Signals from the auxiliary chassis were combined with the main chassis signals in the mixer amplifier, prior to being used for modulation voltage to the associated transmitter.

Preflight and inflight calibration options were provided through use of

an OSU-designed calibrator, model B99KF01A. . This calibrator was originally developed under contract AF19(628)-4993, and details of the design have been reported previously under that contract (Ref. No. 3, Section 3.1.1). The system includes an internal timer to generate a predetermined sequence of calibration steps at lower bandedge, band center, and upper bandedge for approximately 1 second during each minute of flight. It also provides the capability of introducing any of these 3 steps (or the same sequence) through the umbilical control (test) mode. Wiring is so arranged as to permit this "preflight" mode to calibrate all channels, while restricting certain channels from calibration during the inflight mode by the manner in which the control voltage wiring is arranged to the associated relays or MOSFET switches.

Since the model C99SC03 chassis requires not only 28 volt prime power but also plus and minus 15 volt levels for the transfer circuitry, a negative power supply (OSU B32AP01) was included. This unit is a simple dc-to-dc inverter, and has been previously described in Ref. No. 4, the final report to F19628-70-C-0147. Plus 15 volt power was obtained from a tap at the midpoint of the same nickel cadmium battery which was used to supply the prime 28 volt power within the support system.

The combined SCO signal from the mixer-amplifier is used for modulation voltage to a Conic Model CTM-UHF-402E transmitter, on a carrier frequency of 2279.5 MHz. The FM/FM signal from this transmitter is relayed back to the ground from the skin-mounted antenna, a PSL Model 55.805 flush mount stripline array.

3.2.3 The trajectory determination system for this round used the Vega model 302C beacon, exactly as described previously for the sphere support system. Again, beacon antennas were PSL model 7.016, mounted in diametrically opposed pairs on the same skin section.

3.2.4 Controls for operation and service were based upon the same type of circuitry described previously. Individual latching type relays were used for independent control of telemetry power and beacon power. A third latching relay was used for calibrator control, permitting the inflight calibrator to be actuated and then stopped through the control console when the umbilical was in place.

A G-switch (OSU model B99GS01) was added to the payload to start the calibrator into the timing cycle at liftoff. One contact of the G-switch was wired directly to the telemetry power bus and, through steering diodes,

supplied an impulse to all three control relays as the G-switch is actuated at liftoff. This feature is used to insure that all three relays are transferred to the internal power mode at liftoff, in the event launch should ever occur in the external "test" mode of operation.

Battery charging, servicing, and monitor circuits are as described previously for the sphere support systems.

3.3 Ranging Support Systems (DNA series)

A series of packages were also provided under this contract for support of a series of rockets, scheduled to be launched in the Ice Cap 75 series at the Poker Flats Research Range. These packages were fundamentally ranging systems, designed for installation aboard vehicles in which the usage was somewhat different: the majority of these were designed for installation aboard rockets which carried chemical release packages, wherein there was no airborne scientific instrumentation (all measurements were made from the ground to obtain the scientific data). As a result, these packages were designed primarily for minimal vehicle monitors in order to check for proper performance of the launch vehicle. In some cases, additional monitors concerning the release of the chemical were added. Since the altitude at which chemical release occurs is the critical information for the scientific experiment and no radar beacons were carried aboard these payloads, a trajectory determination system involving ranging was devised for use on these rounds. A total of four complete packages were built up at OSU, for Sergeant/Hydac rockets SH75-2 and 75-3 (OSU C36PE01) and for Honest John/Nike/Javelin vehicles rockets HJNJ-75-1 and 75-2 (OSU C36HJ01). Electrical components for two additional packages were supplied to another contractor for mechanical integration within the portion of the vehicle payload being built up at their facility. Although the individual rounds varied slightly, a description of the circuitry for Sgt. Hydac 75-2 will illustrate the type of package involved.

3.3.1 This particular package was built upon a simple disc structure, to go in the base of the payload nose cone. The actual mechanical structure was supported from a Ball Brothers ring antenna, model SBA-1400. (This antenna was designed originally for the Black Brant vehicle and was a very short ring, 17.2" in diameter by approximately 3" in length, which constituted a male-to-female joint and thus could conveniently be installed between the nose cone fairing and the remainder of the vehicle.) All mechanical components were

mounted on the disc attached to this ring and thus occupied only a few inches in the bottom of the nose cone. A 10-channel FM/FM analog telemetry system was employed for monitor purposes and the tone ranging signals from the SDC trajectory determination system available at the Poker Flats Research Range were combined with the telemetry signals on the common S-band carrier signal which was transmitted back to the ground. In order to accomplish the tone ranging, a 430 MHz receiver was required aboard the vehicle to receive the ranging signal which was transmitted up from the ground. The demodulated ranging tone signals were combined with the VCO mixture, for transmission back to the ground. Vehicle performance monitors consisted of sensors for longitudinal acceleration and spin rate, which were assigned two channels within the telemetry complex. An additional eight channels were assigned for event monitors, detecting the time of release of chemical charges from elsewhere in the payload.

3.3.2 The telemetry subsystem consisted of a ten channel IRIG FM/FM analog system on an S-band carrier frequency. To the 10 IRIG subchannels were added the three ranging tones from the receiver output, selected to lie within the bounds of the standard channel 12 IRIG subcarrier oscillator allocation. Telemetry assignments were as follows:

IRIG Ch	Frequency	Data
2	560 Hz	A1 event monitor
3	730 Hz	A1 fuse monitor
4	960 Hz	A2 event monitor
5	1.3 KHz	A2 fuse monitor
6	1.7 KHz	A3 event monitor
7	2.3 KHz	A3 fuse monitor
8	3 KHz	A4 event monitor
9	3.9 KHz	A4 fuse monitor
10	5.4 KHz	Longitudinal accelerometer
11	7.35 KHz	Roll rate (magnetometer)
12	3-ranging tones	

(Ranging tones on 21.34755, 21.728756, and 24.39780 KHz)

The ten SCO frequencies were generated by standard Sonex model TEX-3005 voltage-controlled oscillators, and then combined in an IED model CMA-400A mixer amplifier. The processed tones from the ranging receiver were

resistance-mixed with the output of the mixer amplifier, then used as modulation to the associated S-band transmitter. All SCO's and the mixer amp were mounted in a modified Sonex Model 4055-12 SCO chassis, which had been rewired to accommodate the mixer amp and range tone mixing system, according to OSU drawing B36BE04. The combined signals were used as modulation input to a Conic model CTM-UHF-402C S-band transmitter, and radiated on a frequency of 2259.5 MHz by means of the BBRC ring antenna (Ref. 4, Section 5.5.2).

3.3.3 The trajectory determination subsystem utilized a phase comparison method, in which a series of range tones at the frequencies outlined above were transmitted upward on a 430 MHz carrier signal from a ground-based transmitter. The detected signal from the receiver aboard the vehicle was then relayed back on the telemetry, detected, and phase-compared with the original three tones to determine the distance from the ground transmitter to the vehicle (and thus the slant range from the ground transmitting station to the vehicle while in flight). Although these systems were originally designed to use the Aacom model AR-0900P ranging receiver, the limited supply of these receivers and conflicting usage elsewhere was responsible for modification of the packages to accept an alternate of the Vector model RAH-1113 ranging receiver. All packages were built to accept either installation, with an adapter harness for use in the field. In order to avoid compromise to the other telemetry monitors by noise output from the ranging receiver in the event satisfactory upleg reception was not achieved, a squelch unit was installed between the ranging receiver and the mixed telemetry signal. This unit has been described previously (Ref. 4) and essentially consisted of small module which contained a DC-to-DC power converter which provided balanced $\pm$ 15 volt operating voltages from the 28 volt prime bus. The AGC output from the ranging receiver was fed through an operational amplifier within the squelch unit and used to control the gain of a field effect transmitter, which served to mute the output in the presence of noise (no AGC voltage) and was biased up to an operating point where it served the function of an emitter follower, coupling the video signal through to the telemetry, in the presence of AGC voltage above a certain limiting threshold. The receiving antennas for the ranging subsystem were PSL model 23.020 antennas, which were physically installed on the lower portion of the nose cone which surrounded the disc package at the aft end.

3.3.4 Vehicle monitors were restricted to a longitudinal accelerometer and a magnetometer to sense spin rate. The accelerometer (Conrac model 24158C-10/25-50) was the 5000 ohm mass-loaded swept resistance type described previously. The output signal, in the range of 0 to 5 volts dc, provided an input to the telemetry. Excitation for the accelerometer was provided by a EDC model TS28-5 gage regulator, which provide a regulated 5 volt output from the raw 28 volt bus available aboard the vehicle.

A Schonstedt model RAM-5D-SP magnetometer was used to sense spin rate. Operation was as described previously; the output signal and bias leads were loaded by appropriate resistors within the OSU distribution box and provided a 0 to 5 volt range telemetry data signal.

The monitors of the A1 through A4 events and fuses were actually a combination of circuitry aboard the chemical release portion of the payload, plus signal conditioning networks within the OSU monitor box, model B36PE04. A series of four different resistance networks were provided within this box and, through an interconnecting cable to the Thiokol chemical release package, were connected to a series of optical isolators similar to those described for the sphere payloads. Each indicated that a firing signal had been applied to the chemical release systems for events A1 through A4. Thermal fuses were also installed within the chemical payload, chosen to open at temperatures of approximately 218° F, the temperature anticipated if successful release occurred. The fuses were wired as shunts across the four signal resistance networks, in such a way that a high temperature (which caused the fuse to open) would give an event step voltage on the telemetry system, indicating that the A1 event was followed by high temperature opening the A1 fuse, etc.

Umbilical controls and monitors for this system were extremely rudimentary and consisted of only a 6-pin umbilical connector. A single latching relay within the monitor box provided control between internal and external modes of operation; when in the external mode, power could be applied through the umbilical to the telemetry system for tests. One additional lead in the umbilical complex was used for battery charging and monitor functions, in the manner described previously for the sphere packages. Battery power was supplied by a Marathon 39116 nickel cadmium battery. A G-switch (OSU model B99GS01) was also provided within the instrumentation and wired from the battery through the switch and an isolation diode to the "internal power" coil of the latching relay, thus insuring that the system would be placed in the internal power

mode at lift-off.

Although packages were completed within the OSU Laboratory, the Ice Cap 75 series was later modified in program concept and these rounds were never launched. They were held for some time for potential reschedule, then later considered as of salvage value only, with components removed for use in other portions of the AFGL program.

Ranging receivers, squelch units, and other electrical components were also provided for two other rounds within the Ice Cap 75 series, for installation in payloads which were successfully fired during this program.

4.0 AIRBORNE PCM EQUIPMENT

Under both line items 0001AA (instrumentation for research rockets) and 0001AC (studies and tests for rocket instrumentation systems, leading to design of components), a number of projects which resulted in airborne PCM equipment arose in the course of this contract. Much of the airborne equipment developed as a result of this program under the 0001AC work was then later built in flight configuration and installed as part of the payload instrumentation performed under 0001AA. This equipment represented specialized digital telemetry encoders, designed for compatibility with specific payload design objectives, then later used as modulation for the down-link transmitter to return data from the vehicle to the ground. Projects pursued under this portion of our work included the development of a special complex PCM encoder for the Multi Spectral Measurement Program (MSMP), a dual-output high speed PCM encoder for the Balloon Airborne Mosaic Measurement Program (BAMM), fabrication of a simple small encoder for a DNA payload, development of circuitry for later use on the Infra Red Background Signature Program (IRBS), and a small PCM system designed for use in airbearing tests (to replace an FM/FM analog system) and remain compatible with existing decoding equipment, in order to facilitate payload checks at the Space Vector Corporation facility in California.

4.1 MSMP Encoder

One of the more complex PCM encoders constructed in the course of this project was a special device developed for the Multi Spectral Measurement Program. This encoder had unique and complex timing requirements because the instrument in question provided both digital and analog outputs from a number

of instruments, combined within one complex payload. The instruments had various sampling time requirements, in order to obtain the desired data. Both digital data, developed asynchronously within the Martin-Marieta portion of the instrument, and analog data developed in other portions of the payload, had to be combined into a single synchronous PCM wave train for transmission back to the ground. In effect, the Martin-Marieta portion of the overall payload dictated the telemetry format finally selected, since it provided 14-bit digital words which were generated and stored within the Martin-Marieta instrument in several 1400-bit shift registers (100 words at a time), and required a minimum of 10 samples per second on each such word for transmission downward to the ground. Adopting a format which used 100 minor frames for one major frame permitted each of the Martin-Marieta words to be transmitted downward in the repeating major frame; once this portion of the format had been settled upon, the analog data could be suitably multiplexed and combined within the same overall format.

4.1.1 Data input requirements for processing within this decoder may be divided into several different classes of data.

(a) Ultraviolet (UV) data was derived within the Martin-Marieta portion of the payload in digital form. Three different UV instruments generated digital data as 14-bit pixel words with 100 pixels per scan; one full frame of digital data from each of these three instruments was generated within the Martin-Marieta instrument and stored in three separate 1400-bit shift registers for each of the separate (MSMP-1, MSMP-3, and HSP) portions of the instrument. A fourth instrument (SP) within the Martin-Marieta payload instrument used a 6x6 matrix format for sensors, thus requiring a shift register which stored 36 14-bit words per scan. Since each of these 14-bit words was to be sampled a minimum of 10 times per second and there were 100 sets of words from each instrument to be sampled in each tenth of a second, the frame rate was dictated at 1000 frames per second in order to clock through all these minor frame words at the required rate.

(b) Infra Red instrumentation was from Utah State University and provided analog data to the T/M system; all analog data was coded to 12-bit accuracy and the 14-bit format filled with two zeros at the LSB position. Two of the infrared instruments

required three output words each, and the sample rate of 2000 per second requested for this instrument then doubled transmission at evenly spaced increments throughout the PCM minor frame with six words repeated twice, adding twelve words to the format. Five additional USU data words required sampling only at 1000 per second, so were compatible with assignment within the format already described.

(c) NRL data included electrometers and film experiments, in which the film transport rate was to be monitored through telemetry. Two electrometers and two such film transport monitors required sampling at a rate in excess of 100 samples per second. Using the supercomm technique within the 100 frame subcomm portion of the major frame, repeating every eighth minor frame, permitted a 125 sample per second rate for these bits of information; remaining NRL housekeeping data was accommodated within the same minor frame word by suitable time multiplexing. One additional NRL word (for the NRL rate meter experiment) was assigned as a standard word within the minor frames and thus sampled at 1000 per second.

(d) Housekeeping data from other sources within the payload also required relatively low sample rates, and several were handled on a subcomm basis.

Martin-Marieta housekeeping data included three bits of filter position data for each of the major experiments: HSP, MSMP-1, and MSMP-3. This data was encoded as the first three bits of word number 5, minor frame numbers 36, 37, and 38, immediately following the 6x6 matrix data from the SP experiment. The remaining 22 bits of housekeeping data were sampled at a 10 per second rate by subcommutation in minor frames 40 through 62 of the subcomm assignment in the same word.

Another word in the main frame was assigned to Northeastern University for housekeeping purposes. The 80 NU inputs so involved were transmitted as the first 80 subframe words; Utah State housekeeping data was inserted as the last 20 words in the 100 word subcomm, in order to combine these within the overall PCM format.

Cubic Corporation (ELF-III) signals involved four bits of housekeeping data requiring a sample rate in excess of 100 samples per second, and eight

additional bits of information for which a lower sampling rate was adequate. (A minimum of 10 samples per second was requested for these.) The four bits requiring high speed sampling were presented in a "super-subcomm" format, repeating every eighth minor frame within the 100 major frame to give a sample rate of 125 per second. The eight low sample rate monitors were then inserted within the same subcomm to fill the gaps between super-comm words. Since there were sufficient blanks available, it proved possible to "super-subcomm" these at a sample rate of 30 per second.

Space Vector's housekeeping requirement was somewhat similar to the Cubic Corporation signals, in that six pieces of data for ACS monitors required sampling at a minimum of 100 per second, whereas 12 other monitors required only 10 samples per second. The same technique discussed for Cubic was utilized here, with the six high speed monitors supercommed to give an equivalent rate of 125 samples per second. The frame was then filled with the lower speed samples in the minor frames between the supercomm grouping. Filling the 100 input major frame resulted in double samples on the first eight of the low speed words.

The method chosen to multiplex all of this data in the desired format made use of a long chain of 8-bit multiplexers, and suitable interconnection between high speed and low speed multiplexers permitted convenient generation of the supersubcomm formats desired for those words which required this technique.

Additional requirements for the encoder were that extra timing functions be provided between the encoder and Martin-Marieta instrument for digital data transfer. Several gated bit clocks, properly timed and 14 clock pulses in length, were required to gate the digital data from the instrument in proper sequence. In addition, "unload" commands were required for all four registers as 20 microsecond wide TTL-compatible signals at the beginning of each minor frame. Also required was a TTL-compatible delayed "shift enable" command, ahead of the gated clock for each register, in order to shift data within the 1400-bit instrument register before it was clocked out into the PCM encoder.

One additional signal was required by the Martin-Marieta equipment and generated within the PCM encoder. Martin requested that they be provided a 512 kilobits clock signal, capable of driving TTL logic, for their use within the payload. This was completely independent of the PCM coder frequency, but was generated within the coder through use of a crystal oscillator and an

available divider chip. The output clock signal was fed directly to the Martin-Marieta instrument for their use; it is asynchronous with respect to the clocking of the PCM encoder.

Analysis of the data requirements indicated it would be an advantage to clock all digital input data through the PCM coder, prior to the time of switching to generation of digital words from analog inputs. For this reason, the frame format was organized in such a way as to utilize digital input words through the words 0 through 4 of the minor frame, and also within the fifth word down through the Martin-Marieta SP data and filter position indicators, minor frames 0 through 39 of the major frame. The multiplexing system thus used digital data to this point in the major frame; a transfer was then made to the analog at subframe number 40 in minor frame word number 5. The remainder of the analog data was then multiplexed in the desired sequence, converted to digital form, and fed into the PCM stream.

4.1.2 The PCM wave train finally generated in the encoder was in NRZ-Space code at a bit rate of 392 kilobits per second; 14 bits were used per word, coded most significant bit (MSB) first. A 28-word minor frame was used, resulting in 1000 minor frames per second. Use of 100 minor frames per major frame thus gave an overall sample rate at the desired 10 per second rate for any subcommutated word. The overall format is shown schematically in Figure 2; Reference to AFGL Technical Data Book #77-1, "MSMP Telemetry Data," dated 3 October 1977, may be made for further detail concerning the format used for the telemetry.

The completed encoder was designed to fit along the longitudinal axis of the payload, next to the skin. Constraints were a maximum overall length of 50 centimeters, an overall width of 24 centimeters, and an overall height of 7 centimeters. The final unit measured 46.7 by 23.8 by 7 centimeters, and had connectors on both ends for convenient interconnection with the rest of the payload. Internal to the encoder box, this system was divided into eight discrete circuit modules: all basic timing circuits were combined onto one 28-chip card, shown in OSU drawing D39ME01, card 1. The minor frame multiplexer was shown on the same drawing as card 2 and required 9 additional chips. The analog-to-digital converter was mounted as card 3 on OSU drawing D39ME01. The Northeastern/Utah State University subcommutator was built as a separate subassembly, OSU drawing C39MN11, and required 16 additional chips. The NRL/Space Vector subcommutator, OSU drawing B39MB11 required 8 chips; the Cubic

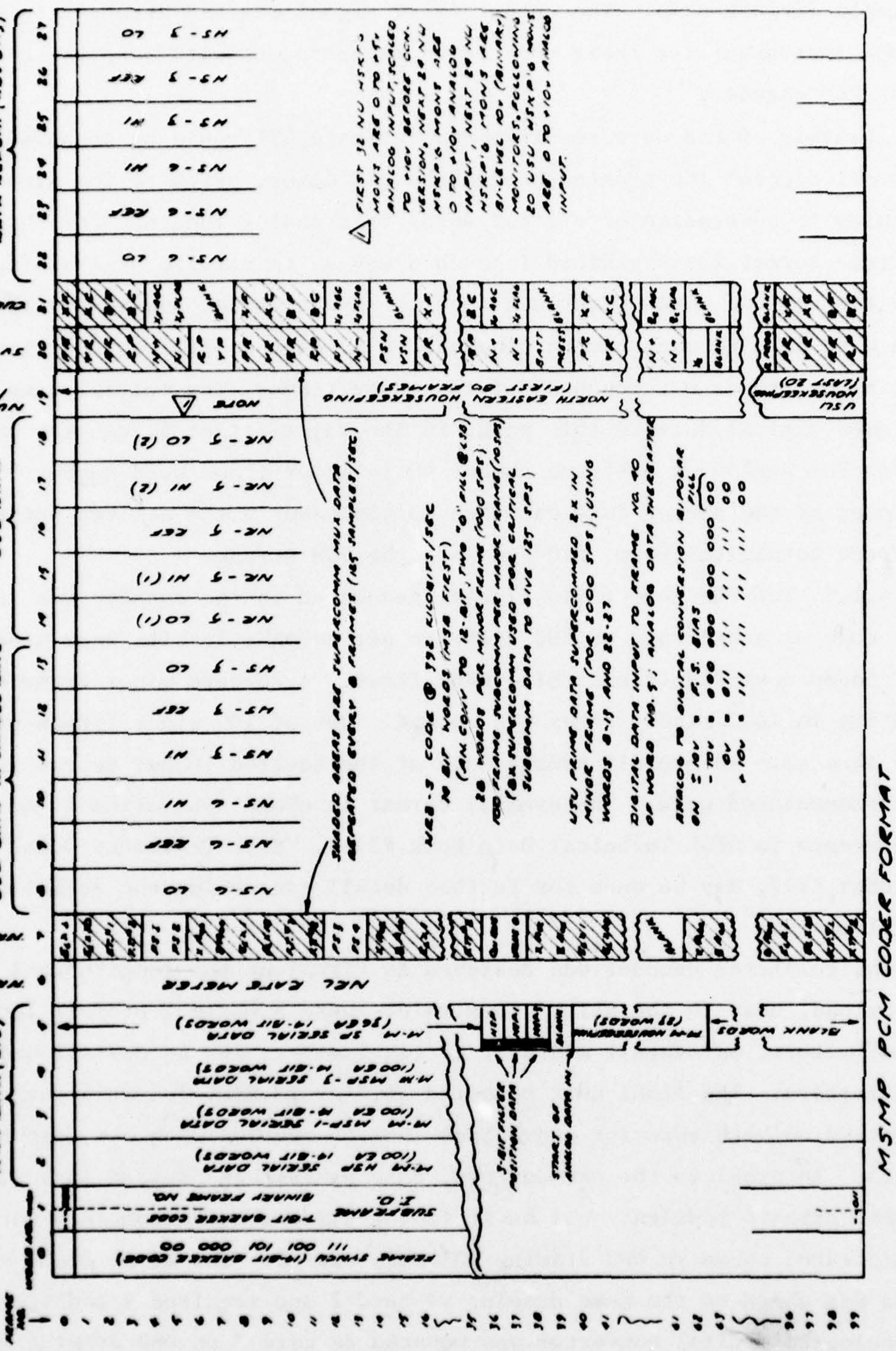


Figure 2. MSMP Data Format

subcommutator is shown on OSU drawing B39MU11 and required 7 chips. The Martin-Marieta housekeeping subcommutator is shown on OSU drawing B39MA11 and required 8 additional chips. A special 28 volt dc-to-dc inverter operated from the raw 28 volt power bus within the vehicle to provide the required voltage outputs at +15 volts, -15 volts, +10 volts, and 5 volts for operation of the entire system. Total power drain from the prime power source was approximately 400 milliamperes at 28 volts input.

The first version of this encoder (supplied for the TEM-1 launch) was built with conventional printed circuit techniques. The three small housekeeping multiplexers were stacked at one end of the case, adjacent to the analog-to-digital converter. The three remaining modules occupied the bottom of the case. The high-speed line driver required to drive the serial wave train from the instrument back to the checkout equipment, added later, made an additional card within this case. Due to failure of the TEM-1 recovery system, this encoder was lost and a second version built up for the TEM-2 payload. The second version was built with wire-wrap techniques and, although superficially identical to the original unit, had a few minor changes. The most notable variation was the combination of the three small subcommutators for NRL/Space Vector, Cubic, and Martin-Marieta, combined on a single card adjacent to the analog-to-digital converter card.

Although CMOS logic was used for minimum power consumption within this unit, requirements to Martin-Marieta experiment were that all output logic circuits must be TTL-compatible. The interface problem resolved by a combination of choice of proper CMOS chips to drive TTL logic, or by buffering where required.

4.1.3 Major timing circuits are shown on OSU drawing D39ME01A. Timing starts with IC101, a clock generator operating at a frequency of 6.272 MHz. This is counted down in one-half of IC102 which operates as a "divide-by-16" counter to provide a bit clock output at 392 kilobits per second, then used throughout the unit. The bit clock from this section of IC102 is fed back into the second section and used to drive a bit counter, which generates a word 14-bits long by combining the 8,4,2 outputs in AND gate IC105B. The gate output is then available as the word clock at 28 kilobits per second, and also resets the bit counter.

The word clock pulses are then counted by IC103; the first half counts groups of eight words and uses the 1/8 count (through gate IC107B) to reset

the counter chip. This signal is equivalent to a slow clock, advancing only on each eighth word, and is taken to one section of IC106, which counts groups of eight words to provide multiplex enable gates. One section of IC116 converts the first and second groups of 8 into a 4-line address code; the third line is taken back through inverter IC108E as an enabling pulse to the other half of IC103. This half, enabled on the third group of 8 words, then counts 4 additional words before generating an output on pin 13, which is used (through inverters IC108A and B, with a slight delay by capacitor C101) as the reset pulse to the word counter at the end of the 28th word, thus terminating the minor frame. This signal also provides a "parallel enter" at time T=0, to set synchronization for the entire minor frame. The minor frame reset pulse is then counted down in the major frame counter, IC104. Reset is derived from IC105C in order to terminate the count on the 100th minor frame, thus establishing the major frame length. Each 100th minor frame generates a trigger pulse to IC115, a one-shot multivibrator whose Q output is taken as the major frame reset pulse, resetting all counters within the system and providing the major frame synchronization to the remainder of the decoder.

As a convenience in handling the mixture of digital and analog input data, a design was so chosen as to present all digital data in the first portion of the format, transferring to analog data at frame #40 in word #5, immediately after transmission of the last digital data derived from Martin Marieta.

Timing signals to Martin Marieta are also derived within the main timing sequence. These signals include the gated clock pulses to the four instruments (HSP, MSMP-1, MSMP-3, and the SP and 3-bit clock). IC114 is used as a demultiplexer, to generate groups of gated clock signals. OR gates IC107A and C serve to enable the two halves of the chip at the proper time to generate eight one-word long strings of clock pulses, in the desired synchronism for coder operation. IC107A enables the demultiplexer during the first four words of the first group of eight words; the bit clock is then stepped in such a way as to provide a sequence of clock pulses on separate output lines, timed to agree with words 0 through 3 when controlled by the A1 and B1 addresses. Inverter IC108C inverts the OR gate drive for the second half of IC114. The same clock pulse gating sequence then results for the second 4 words (4 through 7) in the minor frame. The four gated clock signals for Martin Marieta (words 2, 3, 4, and 5) are then buffered by sections A through D of IC113 to provide the TTL logic drive to the instrument.

The "unload" command to the Martin Marieta digital output registers is derived by triggering one-shot IC111A with the major frame reset pulse. The time constant is so chosen as to provide the required 20 microsecond long "unload" command to all Martin registers, at the start of the major frame. (IC113B is used as buffer to provide the drive to TTL circuits.)

The "shift enable" command to the Martin-Marieta instrument is provided by triggering the IC111B one-shot multivibrator with the minor frame reset pulse. The $\overline{Q}$ output sets flip-flop IC112 to create a properly timed "shift enable" command, disabled at the eighth word in the minor frame by the reset connection back to the "words divided by eight" clock. Buffer IC115D provides the Martin-Marieta signal. Word "0," the frame sync word, is generated by shift registers IC109 and 110, connected to generate a 14-bit Barker code, parallel entered at T=0 by the major frame reset, then clocked out by the gated sync clock pulse train from IC114 during word "0."

A similar word generator function is performed by IC117 and IC118, connected as a 14-bit shift register with the seven most significant bits to generate a Barker code word and the last seven bits used as subframe identification, counting binary increments derived IC104, the minor frame counter. The signal is shifted out of the register by the gated word 1 clock from IC114. The frame sync and subframe identification, words "0" and "1," then provide the first two inputs to the digital multiplex switching circuit to be described in the following section.

A compound multiplexing system is used to time sequence the desired data inputs internal to the encoder. IC116 serves as a counter to generate "enable" signals to the four 8-input minor frame multiplexing chips. This counter operates on the "words divided by eight" clock, derived in minor frame multiplex enable counter, IC106. Successive groups of eight words are counted in sequence. The output for words 0 through 7 enables the first chip in the multiplexer chain, then next following group of words (8 through 15) enables the second chip, the next following gate (for words 16 through 23) the third chip, and finally the fourth chip (words 24 through 28), terminated by the minor frame reset pulse generated by the minor frame word counter.

The digital words are first multiplexed into the data stream through IC205, which has been enabled by words 0 through 7 and has as its "0" input, the clocked-through pulse from the frame sync shift register. Subframe identification is next clocked in as the word 1, then Martin Marieta digital

inputs are clocked from the HSP register to following word 2 , MSMP-1 to the next following word 3, and MSMP-3 to the next following word 4, and SP (plus 3 bit data clocks) to the next following word 5. The last two inputs to this digital multiplex chip are left disconnected, therefore no signals will be generated at the output. The digital output train for words 0 through 5 in the minor frame are thus clocked out in sequence from pin 12 into IC204, a 14-bit delay register which was added to accommodate the delay encountered in converting and clocking in the analog words, after conversion to digital form.

Chips IC207 through IC210 are used to multiplex analog data into the system in the desired sequence. The lines are left blank for the first five inputs (corresponding to the five words which are clocked through in digital form). During this time interval, no data is fed through the analog multiplex chips because the input is open; at the same time digital data is being clocked through IC205 (and the delay register) into the output gating sequence which will be described later. The remainder of the data needed to fill the minor frame is then connected to the analog multiplex chips in the desired word sequence and clocked through by virtue of the time of enabling and the 1, 2, and 4 address lines which are supplied from the word counter IC103. The net result is that analog data appears on the output bus, starting with the Martin Marieta housekeeping data in the late minor frames of word number 5.

The time multiplexed analog signals are fed through IC206, an operational amplifier, to provide a buffered drive into the analog-to-digital converter. A "convert command" is supplied to this converter at the time of bit number eight in each word. Conversion and settling time is permitted during the time equivalent to bits 8 through 14 of one word. The 12 bits of converted digital data are parallel-entered into shift register IC201 and 202 for clocking into the bit stream at the start of the next word. Note that, since conversion occurs for only 12 bits, shift register IC202 is wired to insert two filling "zero" bits at the least significant position, thus providing a full 14-bit word.

Each word of the minor frame, after digital conversion, is then clocked through by bit clock pulses, buffered and scaled from the 5 volt conversion output level to the desired 10 volt level by IC126A, then entered into the gating system for transmission to the output bit stream.

Gates IC124 and IC125 serve to transfer data between the true digital input and analog-converted digital data streams in the pulse train for the

PCM coder at the desired times. IC124B and C are controlled by the Q and $\overline{Q}$ gates from the data control switch, IC128B. These transfer from the digital data stream first six words (0 through 5) and to the analog-to-digital stream for the last part of word five and the remainder of the frame. The resultant wave train is gated through IC125A into the output circuitry. Because word five of the data train is digital data for the first 39 minor frames, then transfers to analog data for subcommutation thereafter, C124A and D (together with IC125C) serve to generate the proper gating signal to make the transfer from clocked in SP and filter position data to converted analog housekeeping data at the proper time. Transfer occurs on minor frame number 40, during word number five. IC128A generates the time for this transfer function by being set by the 40th minor frame in the subcommutation sequence, then being reset by the next following major frame sync. Its Q output is then taken through AND gate IC124C and combined with the word signal from AND gate IC105A to set the data output switch control, which is then reset by IC116 at the end of the next major frame.

IC127 is used to introduce a one-half bit delay, to standardize pulse width (since the first pulse of the train is distorted by the timing sequence) and then convert the NRZ-Level signal to the desired NRZ-Space code. The NRZ-S output is buffered by IC126C and fed to a deviation control potentiometer, which then provides the modulating signal to the associated PCM transmitter. The buffered NRZ-S wave train is also fed through a line driver to a second output connector. This allows hardwire input to the blockhouse, using the line drivers described elsewhere in this report.

The last 60 frames of word 5 and all of word 7, word 19, word 20, and word 21 are subcommutated data. Subcommutation is achieved for each word by a series of 8-input multiplex units, timed by the master timing circuits previously described.

The Martin-Marieta housekeeping functions are inserted in the latter portion of word five by a subcommutator shown in OSU drawing D39MA11. The action is somewhat as described for multiplexing within the minor frame structure: IC401 is used to multiplex digital data into word five during first 38 frames. Minor frames 0 through 35 are clocked through as the SP digital data, in conventional configuration. Frames 36, 37, and 38 are clocked through as the first three bits for filter position data only; frame 39 is grounded and the timing is such that no digital data is clocked through the IC401 chip.

Timing to enable the subcomm multiplexers is also generated on the main timing card, by gates IC120A through D in conjunction with the 2-to-4 line decoder chips, IC121 and IC122, in the same manner described for the minor frame multiplexer. These chips generate a series of enabling gates to the major frame multiplex enable circuits, each eight frames long. Clocking is done on the basis of the major frame multiplex enable counter IC106, OR-gated into the four sections of IC121 and IC122 in such a manner to convert the two address lines into groups of eight consecutive minor frames within each major frame. Enable gates 0 through 7, 8 through 15, etc. down to 96 through 99 are provided. The reset pulse from the major frame counter established synchronism for these multiplex controls. Analog data is gated into the multiplex system, beginning with minor frame number 40 in the word number 5 position; the addressing and enabling gate system carries the sequence through word 62; the remainder of this word within the major frame is then left blank, since there is no further data connected to the multiplexer inputs.

Subcommutated data has been described previously as requiring supercommutation techniques for certain words within the data stream, to provide the desired 125 per second sampling rate for certain data inputs.

Figure 3 (B39MB11) is typical of the technique used, and shows the analog subcommutation used for the NRL data in word number 7, and also for Space Vector data in word number 20. Flip-flop IC507 is used as a binary counter, set by the frame reset pulse at time T=0. Minor frame counted-down pulses (from the 1, 2, and 4 word lines of the major frame timing circuit) are also brought to this card, buffered by IC508, and used to address IC501 and IC504. Both of these serve to insert the supercommutated data in a repeated sequence, repeating every eighth frame within the major frame. Addressing is in the conventional manner from the 1, 2, 4 line inputs; the sequence of output data is determined by input wiring to the multiplex chips. In the case of the NRL subcommutator, data inputs 0, 1, 2, 3, 6, and 7 are wired to be supercommed and thus repeat over and over. IC505 and 506 may be viewed as sub-subcommutation timing circuits, in which the output of IC505 is inserted as a number 4 input to IC504, but is advanced only each eighth minor frame. Similarly, IC506 subcommutates inputs to the number 5 position of IC504, and also advances every eighth frame. The net result is that the low speed data is inserted from different bus each time the high speed multiplexer sequences through the eight consecutive signals.

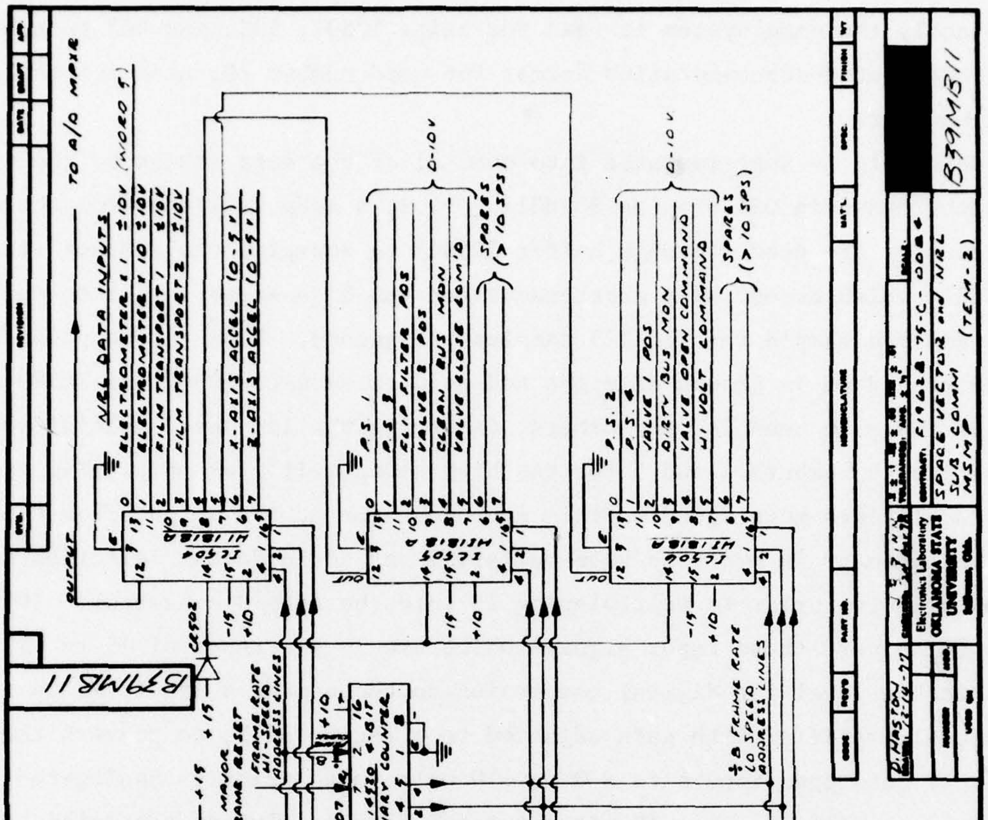


Figure 3. MSMP Supersubcommutation

Exactly the same system is used for chips IC501, 502, and 503 to achieve a supercommutated-subcommutation format for word number 20, used for the Space Vector monitors.

Cubic data is subcommutated into word 21 of the data stream by the subcommutator shown in OSU drawing B39MU11. 1, 2, 4 address lines from the minor frame counter are used (through buffer IC508) to energize the address lines for IC301, which essentially supercommutates the high speed data into word 21 at the desired sample rate of 125 samples per second. Minor frame pulses are also counted down in groups of eight and used to advance IC302 and IC303 at 1/8th of the rate used for the others, inserting the low speed multiplexed data as inputs numbers 4 and 5 for the high speed multiplex chip. Two operational amplifiers were added to this subcommutator at the output from the low speed multiplexer in order to give buffering and scale factor selection for the analog data, prior to multiplexing it into the A-to-D converter. IC305 serves to convert those input signals which are in the range of +5 to +12 volts to a suitable level for digital conversion on the number 4 input; IC304 is an operational amplifier with gain adjusted to a factor of 2, to convert the zero to +5 volt data span inputs to a 0 to +10 volt range prior to analog-to-digital conversion action. (Supercommutated data is already presented to the unit on a 0 to 10 volt scale, or as normal bipolar ±10 volt scale factor data.)

IC306 serves as the multiplex enabling gate, generating "enable gates" at 1/8th of frame rate frequency by counting down the minor frame counter address lines. These enable gates are used to sequence properly IC302 and 303 for the subcommutator lines.

A separate crystal controlled oscillator is included on this card to generate the 512 KHz clock to the Martin-Marieta instrument. IC307 serves as a 4.096 MHz crystal-controlled oscillator, whose raw output is divided down in the second section of IC306 by a factor of eight. The output pulses, a symmetrical clock at a frequency of 512 KHz, are then fed through buffer IC508 to the Martin-Marieta instrument.

Northeastern University and Utah State University share the subcommutated word 19 position in the format. A series of Harrison 1818A 8-bit analog multiplex chips are used in a cascaded sequence for conventional subcommutation of this data.

The first 32 inputs to this analog system for multiplexing are 0 to +5 volt analog signals, from Northeastern University housekeeping. These are

sequenced in the conventional manner, using the 1, 2, and 4 lines from the minor frame counter, together with eight minor frame long "enable gates" from the major frame "multiplex enable" counters on the master timing card. (The common output from these four multiplex chips represents the first 32 frames of the word 19.) Since they need scaling to the proper level, they are taken through operational amplifier IC609 (gain of two) to one input of IC607, which will be used as a transfer switch to the analog system multiplexer. The next 24 inputs to this system are 0 to +10 volt Northeastern University analog signals, and are multiplexed in the same way but taken to second input of IC607. The next 24 inputs in sequence are also Northeastern University signals for 0 to +10 volt range and are bilevel in nature. They are combined with the outputs from IC615 through IC617 by proper sequencing through IC601, 602, and 603. The final 20 inputs to complete the frame are Utah State University housekeeping signals at a level 0 to +10 volts; these are simply multiplexed in the same sequence and combined with the +10 volt Northeastern University signals. IC608 receives the major frame reset and a "set" signal at the time of the thirty-second minor frame, from the minor frame counter in the master timing card. This applies a transfer signal to IC607, thus feeding through the amplified analog signals during the first 32 minor frames, then transferring to the raw 0 to +10 volt level signals during the remainder of the subframe. The output signal is then taken to the analog-to-digital multiplexer in the main timing card.

The double sample rate signal (required at 2000 samples per second for the 6 high-speed Utah State University signals) is accomplished by word allocation within the minor frame format. Reference to the analog multiplex sequencing on the main timing card will show that the inputs which correspond to words 8 through 13 in the minor frame are duplicated by being wired as inputs for words 22 through 27. This inserts them at equally spaced intervals within each minor frame, thus the desired sample rate is obtained in the output pulse train.

4.2 BAMM Encoder

One of the more complex PCM devices developed during this contract was a special 2-link PCM encoder for the Balloon Altitude Mosaic Measurement (BAMM) program. This unit combined both analog and digital input data, digitized the analog data, stored digital data received at asynchronous rates for later

retransmission at the desired synchronous rate, and multiplexed the entire vehicle payload data into a single coder, deriving two coded RF links for transmission to the ground. Two separate similar PCM output streams were provided from the encoder, differing only in the frame synchronization coding and the source of some of the data in words 3 through 10. Because of the high sample rate and large volumes of data required, together with high resolution requirements, it was necessary to use two links at 1.344 megabit per second rates in order to maintain compatibility with bandwidth restrictions in the data transmission links and associated ground support equipment. Both links used 14-bit word length, with most significant bit (MSB) first and NRZ-Space coding. The minor frame length of 11 words allowed a 14-bit synchronization word, followed by ten 14-bit data words. Subcommutation was used, requiring a major frame length of 64 minor frames for one complete data presentation. The completed encoder was assembled in a suitable container approximately 15 centimeters high by 22 centimeters long by 25.5 centimeters wide, with a gross weight of approximately 5.5 kilograms. Physical configuration was as depicted in OSU drawing D39BC01. The large size was partially necessitated by the requirement of a multiplicity of special electrical connectors (which occupy one complete face of the coder) to permit the necessary electrical interface to various portion of the payload. Internal power supplies were provided, and interconnections within the BAMM payload to housekeeping data involved use of a remote multiplexer unit to assemble in serial form the desired housekeeping data for transmission to the main encoder. The system has been described more fully in a Technical Report (Reference 5)

4.2.1 The format of the PCM signal for one link is shown in Figure 4. Data processed by the coder for transmission to the ground included analog outputs from sixteen different infrared sensors in the interferometer portion of the instrument. Each such sensor was monitored with four different amplifiers, with gain factors of 1, 4, 16 and 64. The analog output from the proper gain range for each sensor was automatically selected and converted to 12-bit minor frame digital data. This data was received at the interferometer scan rate, which was somewhat variable and not synchronized with the coder. As a result, it was necessary that this digital data be stored in a memory buffer, together with a 2-bit binary identification of the amplifier selected for conversion to digital form, and then fed back out of memory for transmission at the synchronized bit rate. Since 16 interferometer words were

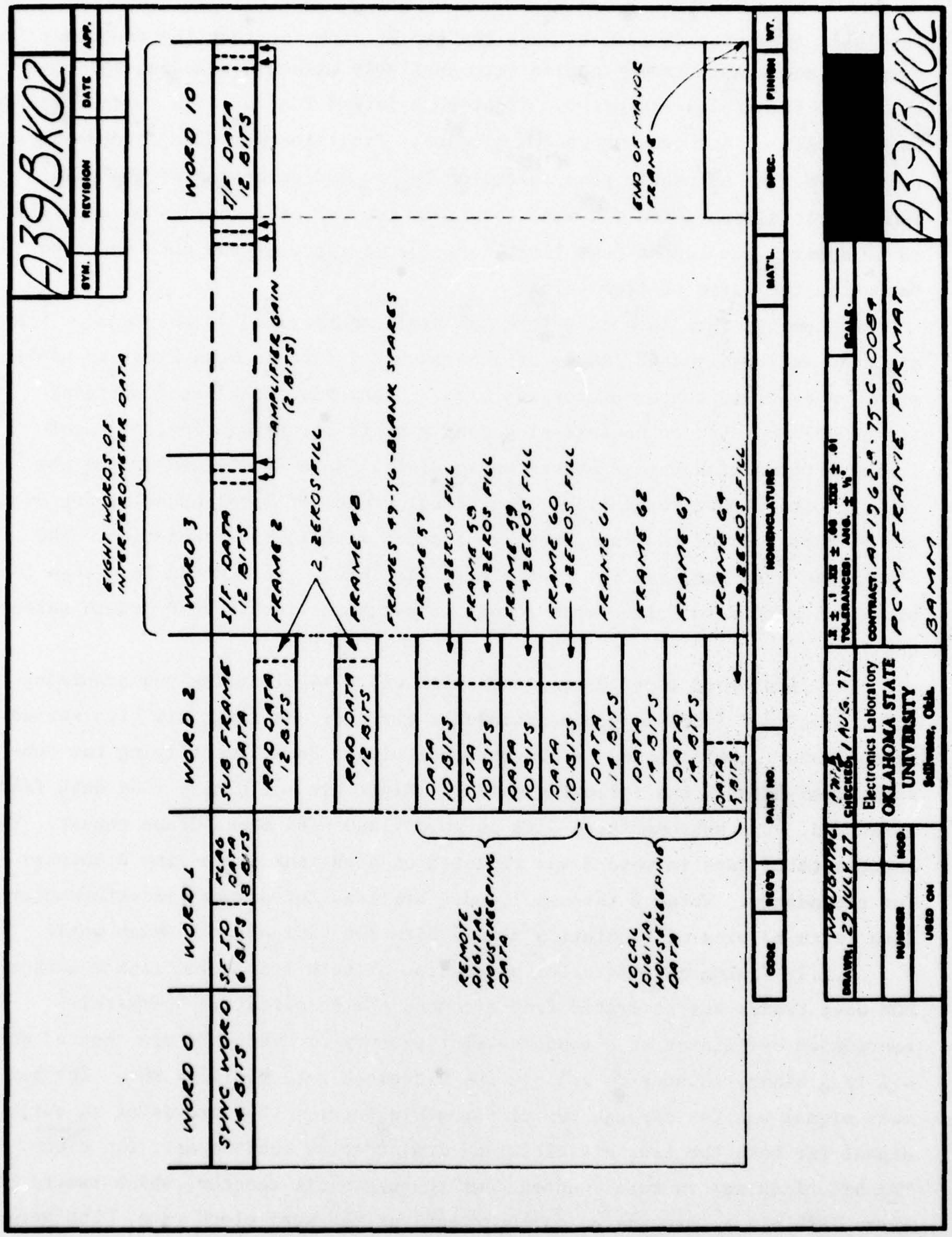


Figure 4. BAMM Data Format

involved, they were divided between the two RF links so that the frequency response and sample rate required were available without exceeding the capability of the ground equipment. Eight such interferometer data words were fed back on each of the two output PCM streams. Provision was also incorporated to override the automatic gain selection by command selection of the gain; one additional provision was made to permit two selected sensors on each link to be supercommutated at four times normal scan rate, if the data observed warranted this type of resolution.

Radiometer data in analog form was also incorporated in the encoder input signals, and required 48 frames of subcommutated data in word 2 for transmission. A 64-frame subcommutator was used. Eight additional subcommutator frames were devoted to housekeeping data with 12-bit resolution, four more frames accommodated remote housekeeping digital data from elsewhere in the vehicle with 10-bit resolution. Four final frames of local housekeeping from the main portion of the instrument were added with 14-bit resolution. The 64th frame also was used for five binary flag bits. (All words less than 14 bits in length were filled with zeros, to match the 14-bit word length selected.)

The first word (word 0) for each link was a 14-bit frame synchronizing word. The next (word 1) group included a mixture; the first six bits served as subframe identification in conventional binary form, identifying the subcommutated data in the following word 2. Eight bits of binary flag data filled this word. The subcommutated data in word 2 had a 64 minor frame repeat. The subcommutated data in word 2 was repeated on both link A and link B outputs for redundancy. Words 3 through 10 were utilized for primary interferometer data (with 12 bits of resolution plus 2 bits identification in each word).

4.2.2 Timing circuitry for generation of both link A and link B output PCM wave trains was generated from a common timing circuit. A crystal-controlled oscillator at a fundamental frequency of 5.376 MHz was counted down 4:1 in a binary counter to achieve the bit clock rate of 1.344 MHz. The bit rate signal was fed through two different inverters, thus providing an output signal for both the true bit clock and its negative counterpart, the $\overline{\text{clock}}$. The bit clock was in turn counted down through a bit counter, which resets on every 14th bit to provide an output signal at the word clock rate. The word clock rate was again counted down through a frame length counter, to provide minor frame synchronization at the end of each eleventh word. The minor frame

synch pulse is utilized to reset all minor frame timing circuits for both links. Frame synchronizing words (which differ for links A and B) are parallel entered into respective shift registers for each link, just prior to word zero, by gating word number 10 with the word clock pulse. The shift register output for each link goes directly to a serial data output OR gate, to provide the synchronizing word out. The serial input to each frame synchronizing generator is grounded, so a series of zeros are clocked out following the synchronizing pattern until the next minor frame "parallel enter" pulse is received just prior to the following word number zero.

4.2.3 Major frame timing for subcommutation is derived from the minor frame timing. A binary counter is advanced by the negative going trailing edge from the eighth output of the basic word counter. This word counter resets itself from the $\div$ 64 output, to generate a major frame length of 64 minor frames. The six binary counter outputs from the same counter are parallel entered as the first six bits to a shift register during the minor frame synchronizing word, word zero of each frame, and are clocked into the serial bit stream during word number one to serve as an identification of the subframe data which will follow in word number two. Word number one consists of subframe identification for the first six bits, and a series of eight flag-bit binary data indicators for the remaining bits are entered into the shift register by the first output of 1-in-4 decoder chip, driven by the word counter. Word two consists of the associated subframe data; it is gated into the bit stream in the proper sequence by parallel entry into a shift register and clocking through by the gated bit clock. A flip-flop is used to disable the 1-in-4 decoder at the end of word two, until it is reset by frame synchronization for the next following frame sequence.

The 1 output of the same 1-in-4 decoder not only parallel enters word 1 into the shift register, but also gates a bit clock to all digital housekeeping shift registers. This then clocks the digital housekeeping data into a storage register during word number 0. The output "4" signal from this same decoder will then gate the bit clock into the storage register to clock data through the output gates during word number 2, at the correct subframe position.

4.2.4 Radiometer data in word 2 is analog in nature and is derived from a 12-bit analog-to-digital converter. The analog input signal to this converter is multiplexed from a series of seven 8-channel analog multiplexers.

The first 48 of these multiplex inputs are used for radiometer data; eight spares are left for additional housekeeping. The multiplexers are driven from conventional 1, 2, and 4 address inputs, derived from the minor frame counter and enabled in sequence by a 1-in-4 decoder. A following binary counter is advanced by the negative going trailing edge of the "4" output from the minor frame counter, thus advancing the binary counter every eight minor frames to program "enable" gates to the seven multiplexers in the proper sequence.

For each such analog input word, the converted digital word of 12 data bits is parallel entered, together with two zero bits as fill, into a 14-bit shift register and will be clocked into the bit stream during word number 2. Word number 2 is switched from analog to digital housekeeping data by a set-reset flip-flop, which is advanced by the minor frame counter at frame number 55 and reset by major frame sync at frame 0.

Eight housekeeping words are also included in the subcommutated data. These exist in parallel digital form for input to the system. Four of these words are generated from the remote housekeeping circuit and are parallel entered directly into a set of shift registers, located in a remote unit, by a parallel to serial converter. In order to minimize leads betwen the remote unit and the main encoder, a minor frame counter has been installed in the remote unit thus programming the remote multiplexer in proper synchronization with the main coder. Digital housekeeping data is parallel entered into the appropriate shift register by minor frame word number 10, then clocked into storage in the main coder during the time of word zero. The counter is advanced as soon as the data is clocked out into the serial bit stream. Local housekeeping data is programmed in much the same manner, except the separate minor frame counter is not required since the minor frame counter of the main encoder can provide the required controls to the data multiplexer. Both remote and local housekeeping data multiplexers are enabled continuously; their outputs are combined in an OR gate while data is being clocked out. The circuitry is such that, while data is clocked out from one shift register, zeros are being clocked out from the other. Both are clocked from the bit stream by an AND gate during the time interval used for all the analog data words.

4.2.5 The interferometer data provide the prime information within the BAMM system, and the sample rate required for this portion of the instrument is the factor which determined the bit rate for the coder. The interferometer array includes 16 infrared sensors. All sensors provide approximately 1500

data points per interferometer scan, and the scan rate is approximately 5 per second. Each of these 16 sensors must be sampled after each zero reference crossing. Each of the 16 also must have four separate gain outputs, to insure that full resolution is used appropriately. Since 12-bit analog-to-digital conversion is used for the prime data, two bits must be added to identify which of the four available gain factors is associated with each 12-bit conversion. Since instrument scanning is asynchronous with respect to telemetry data and coding for transmission, a buffered storage system was necessary to insert the converted digital data into the bit stream at the proper time during the coding sequence to the telemetry link.

Sweep rates of 5 or 20 scans per second are available by a command system. In the normal 5 per second scan rate, sensors 1 through 8 are encoded in digital form as words 3 through 10 on link A. Sensors 9 through 16 are similarly encoded as words 3 through 10 on link B. If command to the 20 scan per second sweep speed is used, sensors 6 and 7 are supercommutated at four times normal data speed on link A, while sensors 10 and 11 are supercommutated at the same rate on link B.

All of the interferometer sensors are monitored by four amplifiers, which have gains of 1, 4, 16 and 64. Automatic gain selection is used to detect the highest gain amplifier which is not approaching saturation by monitoring each amplifier output simultaneously through four different analog multiplexers. The four most significant bits of each such digitized gain signal are monitored by a 4-input NOR gate and a 4-input AND gate, connected in parallel such that if the bits are all zero or all 1's, an output signal from the gate will control the program multiplexer to select the correct amplifier, which is then fed through for analog-to-digital conversion and transmission back to the ground. This automatic gain select feature may also be overridden by a command control system, in order to select the desired gain range manually from the ground.

4.2.6 Because the interferometer instrument generates a large amount of analog data asynchronously with respect to the data transmission system, it is necessary to derive control circuits for the interferometer data multiplexer, analog to digital converters, and a buffer storage system for both links A and B. A common circuit is used for both links. Blanking signals are generated within the instrument during the sweep turnaround time for the interferometer, and a monochromatic reference signal for alternate zero

crossings is also received as square wave at the scan rate. These signals are used to trigger a one-shot multivibrator which initiates the analog-to-digital conversion sequence if there is no blanking signal. The same multivibrator signal resets the conversion counter and triggers the "data convert command" one-shot multivibrator. Output pulses from the "data convert command" one-shot are used to trigger the "gain select command" one-shot on the leading edge and the data analog-to-digital converters on the trailing edge. The "convert command" signal trailing edge is also used to trigger a one-shot with a time constant set to be slightly longer than conversion time for the data converter. This is used to denote the "end of conversion" for both links, and will trigger the "write disable delay" one-shot, to advance the "conversion counter" and step the data multiplexer to the next sensor. The same signal will also trigger the "convert command" one-shot again to initiate the next conversion sequence. Retriggering is stopped after eight conversions in the five sweep per second mode of operation; for the 20 sweep per second mode, the command signal disables a gate in order to permit supercommutation of the first two multiplexer input signals. The "end of conversion pulse" indicates data is now on RAM buffer inputs, and is used to latch the amplifier identification and white light monitors for transfer to buffer storage as well.

Data must be read out as fast or faster than it is entered in the storage in order to be sure that data is not lost. The choice of operating frequency was made to accomplish this. Since a storage system is used to synchronize interferometer data, it is necessary to have some indication of whether the data stream has "caught up" with data acquisition. The interferometer data words are filled with all zeros as fill whenever the storage buffer is empty. The data stream is counted for "data stored" and "data read" in terms of frames of data. Frame counters for "storage entry" and "storage readout" are advanced by the negative going trailing edge of a signal from the ÷ 8 bus of the respective word counters. A 7-bit comparator compares the outputs of the "stored" and "read" frame counters. When the "frames read" counter overtakes the "frames stored" counter, comparison occurs. This switches the entry system back to fill, beginning with word 1 on the next following minor frame. In the event sweep speed does exceed the data readout capability, a "buffer overflow flag" is displayed as bit 9 of the ID word.

Since the interferometer sweep is generated by a mechanical device, speed

variations may occur. A momentary speed increase could cause data errors, as the analog-to-digital converter might have inadequate time to complete the set of eight conversions between the input reference pulses. As a result, the combined output of the "reference" one-shot and the "write disable delay" one-shot then will generate an error flag if this condition occurs, and the error flag is displayed as bit 10 of the ID word.

Buffer storage is provided by two independent RAM buffer systems for each link. Each memory buffer uses 1024 word storage at 14-bit word length. Data from the memory buffer is parallel entered into an output shift register for each word, during the last half bit of the preceding word. For readout, the timing circuit triggers a "read" one-shot, which switches the memory address inputs to the "words read" counter and simultaneously switches the Memory Read/Write bus input to the "Read" position. Data is then parallel entered from the interferometer to the output shift register, the "words read" counter is then advanced at the trailing edge of the parallel enter pulse and the interferometer data is clocked out into the serial bit stream.

All data internal to the encoder is processed in NRZ-Level format. However, the requirement was that NRZ-Space coded output data be provided. This data must be converted to the different "Space" format before data transmission. An OR gate is properly timed such that the gate acts as a switch, combining clock signals and NRZ-L data signals into single serial string at the gate output. This is accomplished by a type D flip-flop in which data is clocked in by the clock signal and delayed one-half bit, then inverted in such a manner that the toggle reverses state to convert the data stream to NRZ-Space code at the output. The signal is fed through a buffer amplifier to an output control permitting adjustment of the transmitter deviation by adjustment of the level of the NRZ-S stream for each link of the coder.

4.3 Infra Red Background Sensor (IRBS) Encoder Development

Late in the course of this contract, a need became evident for a PCM encoder requiring a number of special characteristics, for use on the Infra Red Background Sensor (IRBS) instrument which is scheduled to be flown at a future date. An analysis of the requirements for this encoder was made and the design philosophy adopted for future construction of such an encoder. Because of some unique requirements, the design philosophy was verified by a breadboard model which included those features which differed from established techniques

in order to verify their suitability. The breadboard was built, feasibility demonstrated, and preliminary circuitry filed for further use. The flight model was not constructed under this contract, but is being built under following contract F19628-78-C-0033.

4.3.1 First constraints in establishing the desired encoder format were concerned with the amount of information to be transmitted, the accuracy required, the sample rate required, and the bandwidth available for radio transmission and data recording on the ground.

The total data requirement called for 27 prime instrument sensor outputs (in 0 to +5 volt analog form), two pyro circuit monitors and two auxiliary words (also in 0 to +5 volt analog form), two subcommutated data words with an eighty frame subcommutation format, and three words which were to be supplied in digital form for conversion and insertion in the PCM pulse stream. Frame synchronizing and subframe identification words were needed, resulting in a total of 38 words required per frame. Worst case resolution was for 14-bit words in some of the digital data; to adopt constant word length, the remaining digital data was filled to 14-bit lengths. Although analog conversion was only on a 12-bit word basis, two fill "zeros" at the LSB end of the word were added to fill the word. The requested sample rate was for an absolute minimum of 450 per second with a more desirable sample rate of 500 per second or better. This indicated a lower limit for the bit rate of somewhere between 250 and 300 kilobits. Since information was not available about the status of some of the sensor input words, a decision was made to use a biphase level format, to guard against loss of synchronization during periods of no data on some of the sensors. Transmission of the 300 kilobits biphase level stream was well within the one MHz bandwidth constraint for the RF link and also permitted direct tape recording without special techniques. Adoption of a 300 kilobit clock rate resulted in a sample rate of 564 samples per second, well in excess of the required minimum. An obvious approach was based upon adapting the circuitry developed for the MSMP coder (described in Section 4.1), which provided the desired mainframe sync word, subframe identification word, a combination of digital and analog data, and subcommutation multiplexing techniques into the format. The analog-to-digital converter utilized in the MSMP coder also appeared quite appropriate for retention. Circuitry could be simplified somewhat by elimination of the necessity for commands to the associated instrument, although the Solar Aspect Sensor required some command

interaction with the encoder to provide some of the digital input information.

The digital data consisted of a shaft encoder for position information, whose output was available from the instrument in a 13-bit digital register with parallel output capability. This could be read into the data stream by parallel entering the 13 bits of data (with a zero fill bit at the LSB position) into a parallel entry shift register within the encoder, then clocking this data into the PCM bit stream by an appropriately gated clock signal.

A Solar Aspect Sensor (SAS) was also involved, whose output consisted of two separate 16-bit words. These words were available within the sensor, but stored in 32-bit serial form. (Of the 16 bits of SAS data, only the first 14 bits were the actual data, since the last two bits were indicators which were not required for transmission.) The 32-bit serial shift register then required serial clocking into the encoder, storage in a parallel entry register, and then clocking out the desired bits into the PCM stream at the proper time. In the process of clocking out the data, appropriate timing circuits would permit deletion of the indicator bits by the fact that clocking system could clock only 14 of the stored 16 bits out before transfer to the next following word.

The digital data would require two instrument readout signals to enter the digital data into the encoder:

(a) An enable signal would be required to the registers for the 32-bit stored SAS data.

(b) During the enable gate, thirty-two clock pulses would be required to transfer the serial data into a serial in-parallel out register within the encoder.

All 32 bits were transferred into a serial entry register within the PCM encoder during the enable gate, which started at T=0 and extended for 32 clock pulses. The enable gate was started with the frame sync reset pulse, which opened a gate just long enough for 32 clock pulses (phased with half-bit delay at beginning and end of the gated clock signal). Data was stored in four 8-bit serial in-parallel out registers as a temporary storage system. Transfer occurred, beginning at the start of the first word (word 0) of the frame. The time involved to clock this data out of the Solar Aspect Sensor and into temporary storage allowed transfer to be completed during word 2. The end of the enable gate was then used as a "parallel enter" command, to transfer from

the 32-bit temporary register to a static shift register in which only the 28 bits desired were stored. (The indicator bits were replaced with zeros.) The net result of the method of data handling was to provide, within the PCM coder, stored digital versions of the shaft encoder data and SAS "A" and SAS "B" words at the beginning of each minor frame. The fact that this transfer and storage function occurred at the beginning of each frame meant that, by properly arranging the word sequence, all digital data could be processed at the beginning of each minor frame in sequence. The circuitry developed for gated bit clocks in the MSMP encoder proved appropriate for use to transfer this digital data from the static shift registers into the bit stream by a digital multiplexer, exactly as used in the MSMP-1 coder.

The analog data was subjected to standard multiplexing techniques, then buffered through an operational amplifier into a 12-bit analog-to-digital converter. One additional requirement was that the two pyrocircuit monitors would be evenly spaced in the frame, involving insertion of one pyro monitor at the middle of the frame and the second pyro monitor at the end of the frame.

The 27 prime sensors were arranged in the order of increasing sensor number, immediately following the digital words. One pyro monitor was inserted in the middle of chain and two subcommutated words inserted in words number 33 and 34. The subcommutated words were followed with a Star Mapper analog word and a chopper reference signal, then ended with the final pyro monitor.

One additional complication within the data to be handled was the fact that 24 bits of the analog multiplex data for one subframe originated aft of the payload as 23 temperature sensors and a reference, all located in the vehicle. Electrical interface requirements and configuration of the system thus suggested it might be a convenience to multiplex this data together, properly timed, aft of the payload and transmit it forward as a multiplexed analog signal, for conversion within the forward encoder installation.

4.3.2 The format developed for transmission of the PCM data for this payload consisted of a 300 kilobit per second biphase level stream, divided into 38 words of 14 bits each. Two of the 38 words were to be subcommutated in 80 minor frames, for low sample rate housekeeping data. Of the 38 word frame length, one word was for minor frame sync and a second word was for subframe identification. This system resulted in 564 samples per second for the prime data words, and a 7 per second sample rate for the housekeeping monitors. The frame was organized with the digital data (frame sync, subframe ID, and three

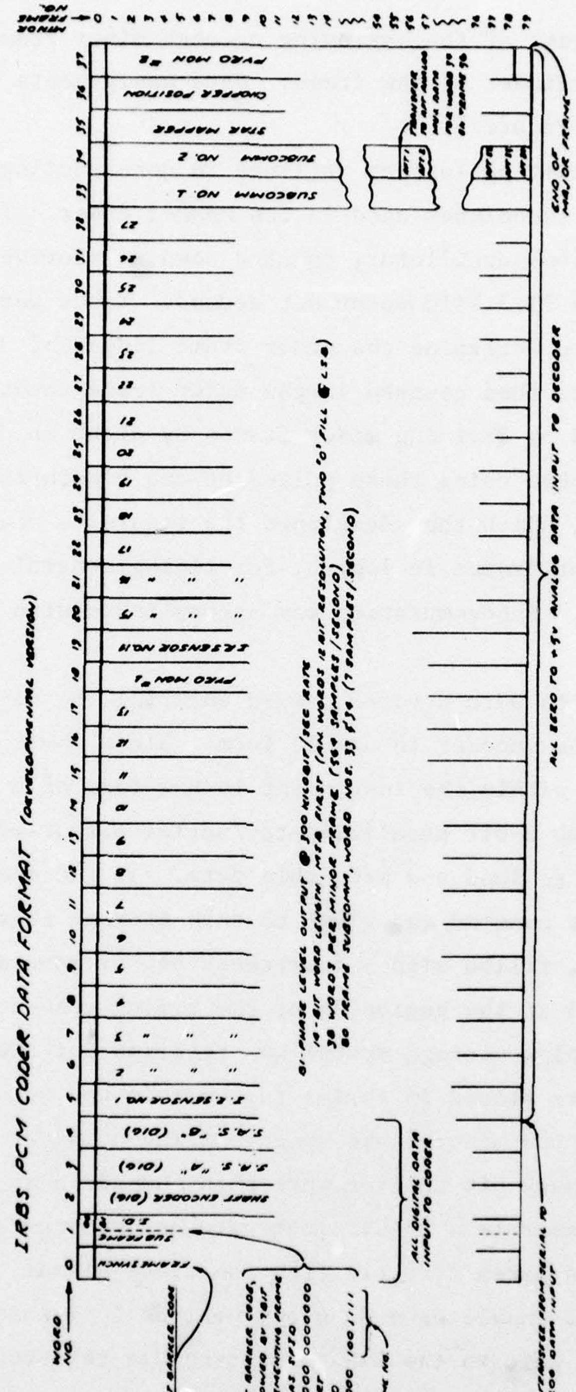


Figure 5. IRBS Data Format

digital data words) at the beginning of each minor frame, followed by analog data for the remainder of the frame. Data assignments within the frame were as indicated in Figure 5.

4.3.3 Circuit philosophy utilized in constructing the breadboard was patterned after techniques used in the MSMP-1 coder. The starting point was a 300 kilobit clock oscillator, counted down to provide 14-bit words at a rate of approximately 21.5 kilo-words per second. Words were then counted down in a word counter to determine the minor frame length of 38 words; 80 minor frame reset pulses were then counted in the major frame counter. Multiplex timing was accomplished by dividing minor frames by eight in one stage of the minor frame counter, then using these pulses at one eighth frame rate into a decade counter-decoder, which then developed the requisite sequence of 10 enable gates, each eight frames in length, for timing control in the associated 80-bit multiplexer. Subcommutation was accomplished with ten 8-bit multiplexers in cascade.

First efforts were devoted toward entering the digital data from the instrument into the encoder in usable form. Since shaft encoder data was already available within the instrument in the form of a 13-digit parallel output register, two 8-bit parallel-enter/serial-output registers within the coder were used to load and hold this data. At the time of frame sync reset, a parallel enter command was given to this storage register, and the 13 bits of digital data, filled with a fourteenth bit of zero at the LSB end, were entered and stored at the beginning of the timing sequence.

A more complex storage system was required for the solar aspect sensor words, which were stored in serial form within the sensor. A set/reset flip-flop was set by the minor frame synchronizing pulse at time T=0. Outputs 32 and 1 from a binary bit counter were then summed in an AND gate to reset the flip-flop and generate a 33-bit long gate as one input to an AND gate; the second input was taken directly from the clock signal. The net result was generation of an enable gate 33 clock periods long which could be inverted and used as the gate to the SAS serial storage register. The gated clock pulses at the input to the bit counter were then run through inverters and buffers to provide TTL compatible clock and $\overline{\text{clock}}$ signals, required for clocking serial data from the SAS instrument into the encoder. (The 33-bit long enable pulse was chosen with proper phasing of the clock gating signals, such as to insure that both clock and $\overline{\text{clock}}$ signals would begin with one half bit delay

with respect to the enable gate.)

At the time of frame sync reset, the enable gate was fed to the SAS serial register and the string of 32 gated clock and $\overline{\text{clock}}$ pulses used to transfer serial data from the serial register within the solar aspect sensor to a serial input-parallel output 32-bit long shift register within the coder. The clocking system used transferred all 32 bits of solar sensor output data into a 32-bit shift register, including the unwanted indicator bits at positions 15, 16, 31, and 32. Serial entry was completed during the time in which the shaft encoder data was being transmitted, permitting the next following word to be available for solar aspect data. The trailing edge of the enable gate (displaced one half clock pulse with respect to serial train) was then used as a parallel enter pulse, to take the parallel outputs from the transfer register as parallel inputs to a standard 16-bit static shift register; wiring was so arranged as to eliminate the unwanted indicator bits in this transfer function, replacing them with zeros at the LSB position of each of the two 16-bit shift registers, which now held digital data for entry to the PCM wave train at the proper time.

A series of gated bit clocks were developed in exactly the same manner used in the MSMP coder, each consisting of a string of 14 pulses at bit clock rate, occurring within words 0, 1, 2, 3, and 4. These gated bit clocks then transferred the data from each of the shift registers in turn to provide the frame sync word, the subframe identification word, the shaft encoder, and the two solar aspect sensor words in time sequence as inputs to a digital multiplexer. This multiplexer, using address inputs from 1, 2, 4 outputs of the word counter, then transmitted these clock pulses through in serial form to the PCM coder. (The 14-bit Barker code word frame sync, and the 7-bit Barker code word followed by a 7-digit, binary incrementing sequence for subframe identification, were also generated in 16-bit shift registers in the manner described in Section 4.1.3 and held for clocking out into the bit stream at the desired time for words 0 and 1).

Data switching was exactly as described for the MSMP system, with the transfer from the digital to the analog input mode of operation at the end of the fifth word in each minor frame. Digital data was fed to one input of an AND gate. A set/reset flip-flop, initiated by frame sync and terminated by the sum of the 1 and 4 words as a reset function, provided a Q input to the AND gate, thus gating through the digital data stream from one input of an OR

gate used to combine digital and analog-converted words.

Analog data was multiplexed through a conventional multiplexer system driven by the requisite enable and 1, 2, and 4 address codes in the proper sequence. To correspond to the first five words of multiplexed digital data, the first five inputs to the analog multiplexer were left open. As a result, there was no output from the analog multiplexer to go to the A-to-D converter (and its corresponding shift register) until the termination of word 5. Beginning with word 5, analog-to-digital conversion occurred with a convert command at the eighth bit of word 5, the converted digital information was stored by a parallel enter command at the end of word 5, and was inserted in pulse stream by the clocking at the beginning of word 6. The analog stream of converted digital data was fed to the second input of OR gate which mixed in words 0 through 5; the combined output was then fed through a conventional system with one-half bit delay to generate an NRZ-Level code of equal pulse width, then convert this to biphase-level (by appropriate addition of the clock signal) in a flip-flop. The output of the biphase-level code form was then taken from the coder to modulate the transmitter. As in the case of the MSMP encoder, a line-driver was built into the decoder to permit the same pulse train to be transmitted through a long coaxial cable from the payload to the associated ground support equipment, for test purposes.

Analog multiplexing of data for words 33 and 34 followed the same general scheme discussed for the MSMP multiplexing, with variations only in the fact that the frame length was only 80 minor frames, and that a decade decoder with series of converters was used to generate a sequence of 10 enable gates (each 8 frames in length) for sequential operation of the 10 different 8-bit analog multiplexers. The "divide by 8" words output from the minor frame counter was used as input clocking to the decade decoder, and reset was applied from the major frame counter at the end of each 80th minor frame. Output from the analog multiplexer was then fed through an operational amplifier to a 12-bit digital-to-analog encoder and clocked into the word stream at the appropriate time.

Because of some constraints in interconnecting pin allocations, the 10 enable gates were generated on each of the two subcommutator cards by supplying only major frame and minor frame sync pulses to a decade decoder card located within each subcommutator card.

The one subcommutated word which had a portion of the frame aft was so

divided as to permit the main multiplexer (within the encoder proper) to handle the first seven groups of eight data inputs, then transfer the output to a multiplexer located in the aft portion of the payload. This multiplexer received the last three enable gates and the 1, 2, and 4 word addresses from the forward encoder to keep it in synchronization and fed the multiplexed analog data up for combination with 56 inputs multiplexed earlier in the forward portion.

The prototype breadboard circuit developed for this purpose was tested and held for future use, in development of flight hardware with the desired configuration, at a later date.

4.4 DNA PCM Encoder

For the DNA series of instruments proposed as a portion of the launch sequence at the Poker Flats Research Range in connection with the Ice Cap 75 program, an instrument known as the "E-Field Detector" was included in one complex payload intended to derive correlated data on a number of phenomena. The characteristics of this instrument were such as to require data transmission of approximately 100 samples per second for the output of eight different data sources. Although generated in analog form, data transmission in 8-bit digital form was requested. Since the vehicle on which this instrument was to be flown utilized an FM/FM S-band telemetry system, an obvious requirement was a necessity for a relatively low speed PCM subsystem which could be utilized to modulate a high frequency voltage-controlled oscillator in the available FM/FM analog telemetry link. The encoder developed for this purpose by OSU was developed in prototype form, qualified, and built in flight configuration. It was then supplied to AFGL, for use by Utah State University as a portion of the Multi payload, Rocket No. IC719.08-1.

4.4.1 For minimum bandwidth in the transmitted link, NRZ-Level coding was adopted for this instrument. The requirement of eight data words at 8-bit resolution and a sample period of approximately 100 per second were met by using a format of PCM coding with a bit rate of approximately 8000 per second. An 8-bit Barker code sync word was used as word 0, followed by eight consecutive 8-bit data words for the eight input signals from the instrument. This yielded a sample rate of approximately 110 samples from each sensor per second. Zero to +5 volt analog data was multiplexed, converted, and then transmitted

serially as the output signal for modulation of channel F (93 KHz center frequency) VCO in the composite "link 1" data, from vehicle to the ground.

4.4.2 The system was developed to utilize low power consumption CMOS logic, for minimum size, weight and power demand, with the unit to be incorporated in the overall payload, external to the telemetry subsystem. Reference to Figure 6 will indicate the circuitry used for this purpose.

A free running multivibrator clock, IC101, was used to generate a square wave bit clock at a frequency of approximately 8000 bits per second. A dual 4-stage binary bit counter, IC102, was then used to count down this bit clock into word and frame rates. The first section of this counter was reset on the count of 8 by a feedback loop, and generated output signals at the word clock frequency of approximately 1000 per second. The word clock was then counted down by the second half of the same chip, wired as a word counter, with frame reset provided through an AND gate from the 1 and 8 outputs, such as to reset the word counter on every ninth word. This permitted the desired timing sequence, allowing for word 0 as frame synchronization and words 1 through 8 as the data words out.

IC103, a decade counter chip, was used to count the bit clock signal in order to generate a "convert command" to the associated analog-to-digital converter at the time of the fourth bit of each word; this counter was reset by the word clock in such a manner as to provide convert commands at approximately the center of each word. (Operation was such that analog data was converted during the word preceding the word to be transmitted.)

Word counter outputs from the 1, 2, and 4 buses were used as the address signals to a conventional 8-input analog multiplexer, IC104. Since the word counter was reset on the ninth word count, these control signals resulted in a two-word long "zero" condition for the multiplexer, allowing insertion of the synchronizing word, prior to resuming the sequence of eight data words within each frame. The analog output from the data multiplexer was fed through an operational amplifier, IC105, to convert the 0 to +5 volt data input into 0 to +10 volt form for conversion because the associated analog-to-digital converter was built for 0 to +10 volt full scale conversion.

IC301, a Zeltex ZD461 8-bit analog-to-digital converter, was enabled at the center of each word by the convert command from IC103. Data appearing at the analog multiplexer output at this time was then converted into conventional 8-bit digital form, and the eight parallel output lines used to address a

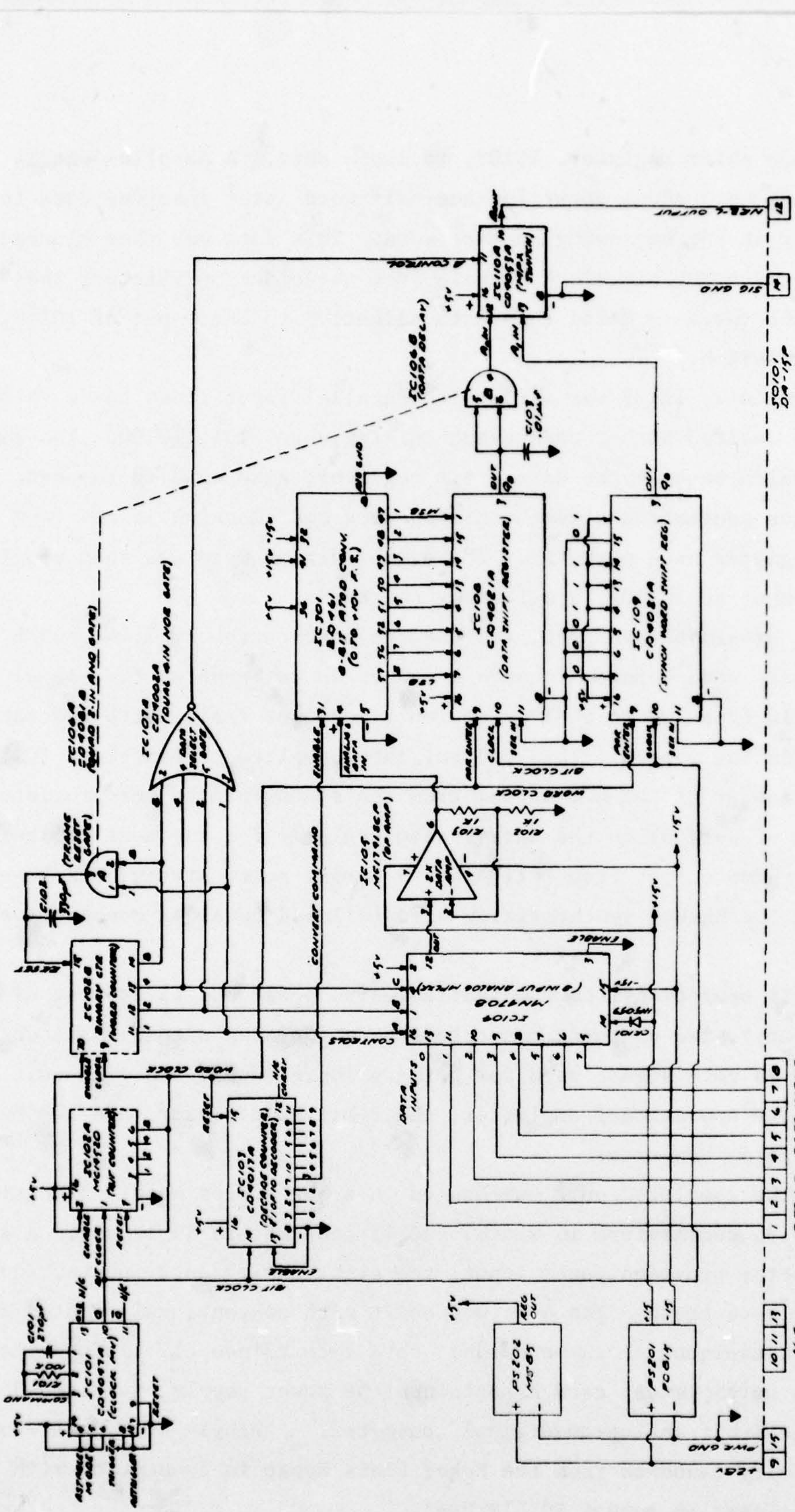


Figure 6. DNA PCM Coder Logic

parallel input shift register, IC108, to store data. A parallel enable pulse from the word clock occurring one-half word later inserted data into the data register at the beginning of each word. This data was then clocked from the shift register by bit clock signals from the clock oscillator, then through IC106B (used to delay this data slightly) to one input of IC110, a multiplexing switch.

Shift register IC109 was wired with parallel input lines to dc voltages to generate the desired Barker code synchronizing word, 101,110,00. The same word clock which enabled the data shift register, also enabled the sync word register, thus generating a synchronizing word and clocking it out from the shift register once per word. The synchronizing word was then applied as the second input to IC110A, a multiplex switch.

IC107A, a 4-input NOR gate, was used to combine the 1, 2, 4, and 8 outputs from the binary word counter in such a manner as to transfer the signal controlling IC110 from "0" to a "1" state only once per frame, with a duration of only 1 word during word 0. This control gate, applied to pin 11 of IC110, resulted in transfer of the bit stream from the synchronizing word register in the position of word 0) to the data stream register for the next following eight words. The output from IC110A was a serial pulse stream, NRZ-Level format, with the Barker synchronizing word followed by eight consecutive 8-bit data words.

To permit operation from the available raw power bus (a 28 volt nickel cadmium battery), two dc-to-dc converters were included within the coder to generate the +5 volt signal used for primary logic supply and $\pm$ 15 volt power required by the operational amplifier, the 8-bit multiplexer, and the 8-bit analog-to-digital converter.

4.4.3 The completed unit was housed in a box approximately 5 centimeters in height, 6.35 centimeters in width, and 11 centimeters in length. A single 15-pin connector provided power input, the eight analog data inputs, and the NRZ-L output wave train. The unit was built with conventional printed circuit wiring techniques on three cards: card 1 contained all timing circuitry and the data multiplexer, card 2 contained the power supply, and card 3 consisted of the 8-bit analog-to-digital converter. A single such unit was built and successfully launched from the Poker Flats Range in connection with the "MULTI" experiment on rocket IC 719.08-1.

4.5 PCM System, Air Bearing Table

A number of payloads flown by AFGL during this contract period have involved the use of an Attitude Control System (ACS) to stabilize the instrument and vehicle while measurements are obtained. Proper testing of the control system and associated payload have made use of an air bearing test facility, permitting the system to be operated in a simulation of the free-flight mode, for evaluation of control system and instrument. To facilitate analysis of data from the freely suspended vehicle during this test, an analog FM/FM telemetry system was previously used to telemeter data from the system under test to a receiving system at the Space Vector Corporation (SVC) facility in California. This required installation on the air bearing table of a multichannel FM/FM analog system, and committed a multichannel analog receiving system to support of these tests, involving a large quantity of ground support equipment. In the course of this contract, OSU was asked to develop a simpler PCM system for support of the air bearing tests, thus freeing the analog system for use elsewhere.

Analysis of the system employed for this purpose and comparison with a similar PCM system already in use on the falling sphere class of payloads indicated that it was possible that compatibility with the airborne encoder characteristics might permit use of the same ground support system developed for automatically decoding data from the sphere as the ground terminal equipment, to decode data from the air bearing table. Since the design of this ground support equipment already existed, duplication of the decoder in a second unit would provide a suitable facility at Space Vector Corporation with a backup unit which could be employed in support of the sphere program at times when not required for air bearing tests.

4.5.1 The original sphere encoder system used a Biphase-Level format, operating at a frequency of 12.8 kilobits per second, with 8-bit word length and an 8-bit Barker word for frame synchronization, with fifteen following data words. A sample rate for all data of approximately 100 per second was provided. Check of the SVC data requirements indicated that this was more than adequate to replace the existing FM/FM telemetry system. Consequently, a second ground station decoder identical to that described in section 7.2 of this report was constructed as a terminal equipment, and an associated comple mentary PCM encoder was built in a configuration such as to readily replace

the physical mounting of the analog system, for installation aboard the air bearing table. Although not strictly speaking an airborne PCM development, the fact that the device was developed in the configuration normally employed for flight equipment, and the fact that it was employed as though it were aboard a free-flight vehicle, indicates it should properly be included in this section of the report. The coder which finally resulted had dimensions approximately 6 centimeters in height, 7 centimeters in width, and 19 centimeters in length. A single 25 pin connector was used for data input and output, compatible with the connector used in the previous analog system. Internal circuitry was as shown in Figure 7, OSU drawing B90FT01.

4.5.2 Circuitry for the encoder made use of a number of subcircuits previously developed for other uses under this contract. The basic bit clock came from a free running multivibrator, IC101, using the same circuitry previously described for the DNA encoder. Output clocking signals at a frequency of approximately 28 kilobits were then applied as input to IC102, a dual 4-bit binary counter.

Raw clock signals were counted down in the first stage of this binary to provide a 14 kilobit clock for timing signals elsewhere; the bit clock signal was also inverted by one section of IC104 to provide a negative clock, for use in shift register clocking, to permit data clocking one-half bit out of phase with the basic clock signal.

The 14 kilobit per second clocking signal was then further counted down in IC102 by a factor of 8, to provide an output signal at the word clock rate and generate 8-bit words.

IC103 served as a word counter, counting down the word clock pulses by a factor of 16 to provide a frame synchronizing pulse. Feedback from the 16th count to the reset bus reset this counter at the end of each minor frame.

The 1, 2, and 4 outputs from this word counter were used as the control signals to two associated 8-channel analog multiplex chips, IC106 and IC107. These multiplexers were then advanced at word rate to transfer data from each input channel, in the desired sequence, prior to conversion of analog data.

The multiplexers were enabled in sequence by using the output from the 8 counter to enable IC106, the multiplexer for the first eight words of the frame, and the inverted version of this signal was used as the enabling gate for IC107, which multiplexed the signals for the last eight words within the frame. Outputs from the two multiplexer chips were combined as the input to

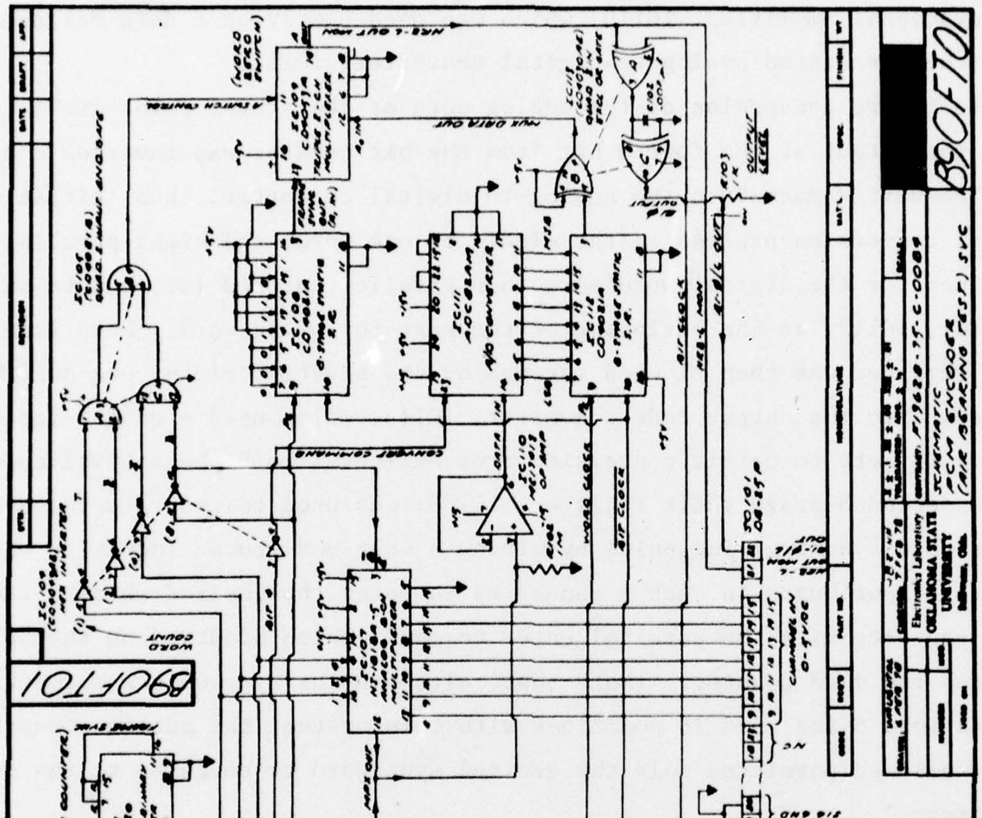


Figure 7. SVC PCM Coder Logic

an operational amplifier, IC110, which was used simply as a data follower to drive the associated analog-to-digital converter, IC111.

To insure conversion of the analog data at the proper point within each word, the output at the fourth bit from the bit counter was inverted and used as a "convert command" to the analog-to-digital converter, thus initiating the digital conversion process in the middle of one word; the eight parallel output lines for the digital word were then parallel entered into a data shift register, IC112, at the beginning of the next following word. Data from the shift register was then clocked through by the negative clock, one-half bit delayed, into the output code converter, IC113, which used a quad 2-input exclusive OR gate to permit conversion from NRZ-Level to Biphase-Level code.

A second 8-stage shift register, IC108, was used to generate the 8-bit Barker word synchronizing pulse by wiring 5 volt and ground inputs to the parallel input buses in such a manner as to enter the desired word to the shift register with the parallel enter command, which occurred on the "8" output from the word counter. (Note that, although the sync word was generated at both word 8 and word 16 positions with this system, the gating circuit which followed permitted only the desired sync word to be gated to the serial bit stream.)

IC104, a hex inverter chip, not only inverted bit 4 to establish the convert command, but also inverted words 1, 2, 4, and 8 to provide their negative complements as timing signals; these were used for proper operation of the multiplexing circuitry, and also for insertion of the sync word during word 0 by a quad 2-input AND gate, IC105. The $\overline{1}$ and $\overline{2}$ word signals were combined by the first section of this chip, and the $\overline{4}$ and $\overline{8}$ word signals combined by the fourth section of this chip. These two combined signals were then used as input to the second section, to generate the desired control signal to IC109, the data transfer switch, which transferred the serial stream from the sync word shift register to the data shift word register at the end of word 0 in each frame. The output of IC109 was an NRZ-Level signal of word 0, the synchronizing word, followed by words 1 through 15 in the proper sequence, all in 8-bit digital form. IC113 served not only to combine data and the gated synchronizing word, but also provided code conversion by using the bit clock (one-half cycle out of phase with the NRZ-Level signal), to generate the desired Biphase-Level output. The Biphase-Level signal is taken across an adjustable output control, R103, to permit adjustment of the deviation of the associated

telemetry transmitter.

As a convenience in system testing, the NRZ-Level output monitor was also provided on the main power connector.

All operating voltages for the coder were provided from commercial dc-to-dc inverter type power supply, which operated from the raw 28 volt input power and provided output voltages at +5 volt and $\pm$15 volt levels for operation of the associated electronics within the unit. This system, together with the associated 16-channel decoder, was supplied to Space Vector Corporation and has since been utilized successfully in airbearing tests of AFGL payloads.

5.0 AIRBORNE EQUIPMENT DEVELOPMENT

Under the requirements of subline 0001AC of this contract, a program of examination of existing equipment limitations and the development of improvements for airborne usage (with subminiature, lightweight, rugged, reliable devices) was continued throughout the period of this contract. Some of these developments were in the nature of modifications to existing equipment by addition of OSU-developed circuitry, replacing items of similar nature which were originally present in the equipment. Similar work resulted in design, testing, qualification and packaging for flight of entirely new devices, to meet needs which arose in payload preparation (where existing suitable components were not available).

5.1 Ranging Receiver Modification

Ranging receivers, procured for use aboard airborne payloads for both tone ranging and the OSU TRADAT system of PCM ranging, were found to be somewhat marginal for the proposed usage in many instances. A relatively large quantity of Aacom model AR-900P receivers were procured, both here and at the facility of an allied contractor. Testing for flight qualification of payloads which used these receivers disclosed that they were not usable for the intended purpose, as received from the vendor, although they met procurement specifications which had originally been drawn up for a different usage. For those applications where the characteristics of the receiver were inadequate for the proposed usage, the entire video module received with the original receiver was removed and replaced with an OSU-developed module of improved characteristics. Eight receivers were modified by replacement of the video module with an OSU module, as depicted in OSU drawing B95AA01. Physical characteristics were made compatible with the mechanical mounting of the

original factory equipment.

The basic problem which led to this modification was the fact these receivers did not have squelch circuitry, or appropriate video-limiting output devices, which were required for the proposed usage. Video output from the receiver was to be used as modulation to a VCO within an associated FM/FM analog telemetry system, for relay back to the ground of data to be used in trajectory determination. As received, the receivers provided a high output noise level in the absence of signal from the ground transmitter. Since the VCO used in the telemetry link was operational any time telemetry checks were being made, a serious disadvantage existed in that it was necessary to operate the ranging system to avoid compromise to other data. This in turn raised the question of potential compromise to the scientific data being carried by the same telemetry link, in the event a failure of the ranging system occurred during the rocket flight. As a result, a circuit was developed to process the raw video from the detector portion of the receiver in such a manner as to eliminate this problem. After successful bench tests simulating the proposed flight environment, a circuit was developed with features suitable for the intended use.

The basic modification consisted of adding a voltage regulator to provide a lower voltage of only 12 volts from the normal 28 volt raw receiver input voltage. This regulated 12 volt then serves both as a source of bias to the video amplifier and collector potential for low voltage operation of an associated video amplifier. The down-regulator was rudimentary, utilizing a 2N4922 transistor with base reference set by 1N4743A zener diode so as to drop the unregulated 28 volts to a regulated level of 12 volts at a cost of higher current load within the receiver. The 12 volts was then divided down and used as a positive base reference voltage for a 2N3904 transistor. Video from the detector of the system was then fed through this biased network as input signal to the transistor, which served as a threshold detector, only providing video output when the level exceeded a threshold set by the input bias. Since the system was to be used with the PCM range-coding system, amplitude variations of the video level would result in variations in the PCM stream used as modulation to the analog VCO channel used in the down link. To set the output level and shape the PCM , receiver output above the threshold level was then fed through a pair of digital logic inverters on hex inverter chip CD4009. The PCM train was thus squared, shaped, and set at constant amplitude by the

digital logic, providing the desired input signal for the VCO. Characteristics of this system were such that no signal was obtained until the receiver video exceeded bias threshold; any signal above this threshold was then squared by the two inverters in cascade, providing a suitable signal to the VCO. The resulting of modulation of the VCO was than a reproduction in reconstituted PCM waveform of the up link ranging signal.

Eight of the AR900P receivers were modified by change to this video card, for use in airborne packages which the TRADAT Ranging System was employed.

5.2 BAMM PAM Commutator

In connection with the preparation of the instrumentation section for the BAMM payload, a requirement for a simple PAM commutator became evident. In the absence of suitable commercially available components for this purpose, OSU proceeded with development of a low power consumption device using CMOS logic. Other requirements were that the system operate from the raw 28 volt power bus within the system and generate a PAM output wave train compatible with standard decoding equipment. After analysis of the data requirements, a choice of the 2.5 x 30 PAM commutator in NRZ format was made for this device. Other unique requirements were that the commutator had to withstand input voltage data swings which exceeded the normal 0 to +5 volt range without damage or compromise to the remaining data being transmitted from the BAMM system, and that internal calibration of the analog channels be incorporated in conjunction with generation of the standard NRZ synchronizing pulse. The design which resulted seemed adequate in breadboard tests, so a prototype system shown in Figure 8 was packaged in a configuration roughly 8.9 centimeters square by 3.8 centimeters in height. A Cannon DC37P connector was chosen, to make this interchangeable with some commercially available commutators of the motor-driven variety which utilized the same input connector. The prototype unit was sent to AFGL for full environmental testing and flight qualifications. After successfully passing these tests, a series of six such units were built in the production version. The design is shown in OSU drawing D39MC01. Units were delivered to AFGL, where some were used in both tests and operational flights of the BAMM mission and others were installed as standard commutators, for telemetry usage on other payloads.

Since development of the prototype and production of the first four units, the design has been reevaluated and a Mark II version, known by the D39MC05 designation, is currently being developed. Although operating characteristics

Figure 8. Prototype PAM Commutator

will be the same, the new unit utilizes later developments in available CMOS chips with a reduced chip count and a higher efficiency. This developmental project will be continued under the following contract, and is expected to go into service as a replacement for the original six units when current stocks are exhausted.

5.2.1 Timing for this commutator is internally derived from a simple sequence of operation. The circuit is shown in Figure 9. IC101 chip is used as the basic clock oscillator. Provision is made for the addition of a small trim resistor to adjust the actual clock frequency to the desired 75 steps per second (for compatibility with standard 2.5 x 30 decommutation facilities). The output from the oscillator is a 5 volt square wave at 75 Hz. This clock is then taken to IC102, a 7-stage binary counter. One, two and four outputs from this chip are used as the address controls for the associated 8-input analog multiplex chips to sequence through four sets of 8 input signals; the "8" and "16" outputs from the counter are used to generate sequential enable gates to the series of multiplex chips, in a manner to be described later.

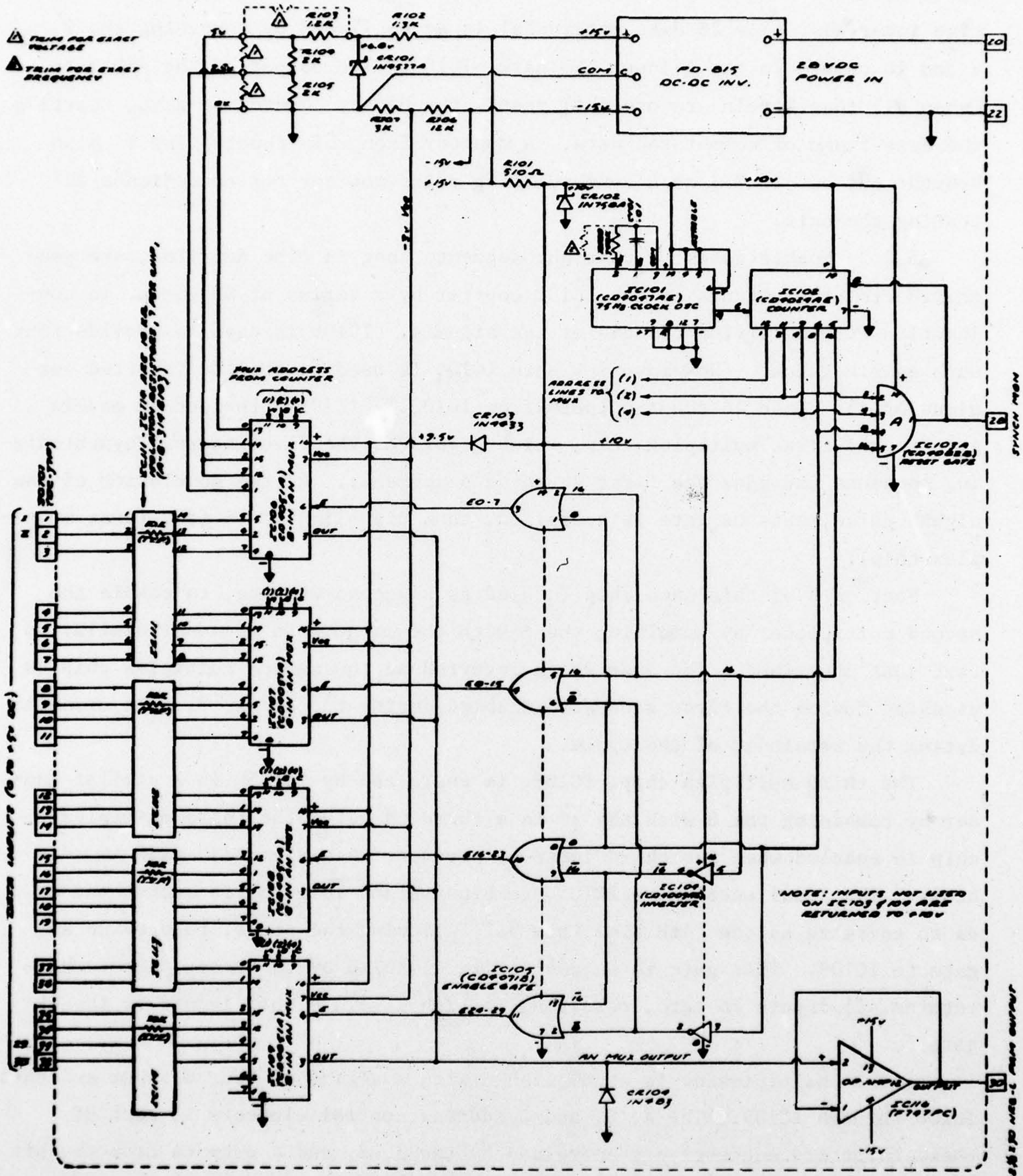


Figure 9. PAM Commutator Circuit

Reset of IC102 after a count of 30 (corresponding to the five synchronizing time intervals, plus 25 data intervals) is accomplished by combining the 2, 4, 8 and 16 counts in the 4-input AND gate, IC103. The output of the AND gate (when all four levels are present) resets the binary counter to zero, starting the next frame of commutated data. A monitor from this reset pulse is also brought out on pin 28, as a synchronizing pulse monitor for convenience in testing the unit.

5.2.2 Enable gates, each eight segments long in time duration, are generated from the outputs of the IC102 counter by a series of OR gates, in conjunction with inversion of some of the signals. IC105 is used to provide four such enable gates. (Hex inverter chip IC104 is used to provide inverted versions of the 8 and 16 count outputs from IC102.) IC105A provides an enable gate to the first multiplex chip, which generates the five interval synchronizing sequence and adds the first three data segments. At the conclusion of the eighth pulse, this OR gate is energized, thus disabling IC106 (the first multiplex chip).

Section B of this same chip is used as a second OR gate, to enable the second multiplexer by combining the $\overline{8}$ with the 16 gate in a manner similar to that just described. The 8 drive is inverted so the second multiplex chip is disabled during the first 8 counts, enabled during the second 8, then disabled during the remainder of the cycle.

The third multiplex chip, IC108, is energized by IC105C in a similar manner by combining the 8 with the $\overline{16}$ in a third OR gate; the third multiplex chip is enabled when the third interval arrives, then disabled again immediately. The final section of IC105D combines $\overline{8}$ and $\overline{16}$ gates in such a manner as to energize on the 24th time interval following the start, to provide a gate to IC109. This gate is automatically disabled by the reset pulse, which returns all inputs to zero, resulting in high level to both inputs to the OR gate.

5.2.3 Multiplexing is accomplished with a series of four 8-input switches, IC106 through IC109. The A, B, and C address control elements to each of these chips are successively energized by the 1, 2, and 4 outputs from the bit counter in IC102. If the multiplex chip is enabled by the proper gate, the chip will selectively advance through its eight input signals. At the end of the last (7) address, the enable gate stops and a corresponding following multiplexer is enabled to repeat the sequence for the next eight inputs.

IC106 provides a sequence including the synchronizing pulse sequence of 0 volts, 5 volts, 5 volts, 5 volts, 2.5 volts, and then the next three following data inputs. IC107 provides the next eight consecutive data elements, IC108 repeats this process for the next following eight, and IC109 sequences through the last group of four inputs, then is reset and the synchronizing sequence begun again with IC106.

5.2.4 Requirements of protection of signal lines and the output data lines were met by choosing adequate chip elements. Multiple resistors (7 each of 10 kilohms) in standard 14 pin DIP socket configuration provide 10,000 ohm series isolation resistors each of these 25 input signal lines, between the input connector and the multiplex input buses. In addition, to protect against loading effects in the event that the data system is operating while the commutator is not turned on, a blocking diode CR103 was inserted in the +10 volt supply bus to all multiplex chips.

Power is generated internally by incorporation of a PD815 power supply, which provides the raw ± 15 volt power required for operation of the voltage follower, IC110, which was provided to buffer the switching from the final output terminal. Diode CR104 also protects this system against negative polarity voltages, outside the range normally handled by the data conditioning equipment.

The -15 volt bus is also tapped down to a level of -3 volts for use as the V_{ee} supply to the multiplex chip. The +15 volt bus is down-regulated by simple shunt zener regulator to provide the +10 volt power required for the CMOS logic chips used within the multiplexer. A second zener regulator with a very low temperature coefficient (6.8 volt level) is used to provide desired 2.5 and 5 volt references. Precision dividers, R103 through R105, are trimmed in each unit to provide precision references at 5.000 and 2.500 volts, which are then multiplexed into the PAM format by the first few segments of IC106 while generating the IRIG standard synchronizing sequence.

5.3 Three-Point Telemetry Calibrator

As a device of possible future application, development was made of a special 3-point telemetry calibrator, for inflight calibration of analog telemetry systems. A number of such designs have existed from past contracts and have been described in previous reports (References 2 through 4). These previous calibrators used electromagnetic relays with ramp generation and

pickoff techniques, using analog techniques to develop the desired sequence of calibration voltages from an internal voltage regulator. They were powered by the prime 28 volt bus within the vehicle, and energized either by an internal timer or through umbilical connections from the blockhouse. Requirements in developing a digital technique replacement were that the blockhouse control requirement (a maximum of four leads against ground) be retained as the only external connections for control of the system through the umbilical, and that operation be from +28 volt power. A calibration sequence of 0 (lower bandedge) 2.50 volts (center frequency), and 5.00 volts (upper bandedge) for standard 0 to +5 volt data span is used for the system being calibrated.

A prototype unit meeting these requirements was developed and tested in breadboard form; the unit has not been repackaged in flight configuration. As originally developed, a calibrator was provided with switching provision to transfer between the data input lines and the calibrator for only three channels of telemetry. Additional channels can be added and multiplexed to the same basic design by simply adding additional FET switch components, CD4053, each of which will accommodate three additional channels. Power consumption is markedly less than for the analog version which it replaces.

5.3.1 A PD815 power supply is used to generate operating voltages required within the unit. ± 15 volt supply buses are used for operational amplifiers; the plus bus is divided down to provide both the operating voltage for the CMOS chips used and the +5 volt and 2.5 volt calibrate levels. As in the case of the PAM commutator, the -15 volt bus is also divided down (by a simple voltage divider) to provide a negative 4 volt V_{ee} reference for the FET switches. The precision 5.00 volt and 2.5 volt supply signal buses for the calibrate function are provided from a zener regulator, CR102, a 1N653A running at 6.2 volts. A potentiometer across this zener permits adjustment of the 5 volt level, and the 2.5 volt level is obtained from a 1% voltage divider across the 5 volts to ground. In order to provide a low impedance source for calibration voltages, both the 5.0 volt and 2.50 volt signals are run through operational amplifiers, and a simple voltage follower configuration (IC101 and IC102) uses standard type 1741 operational amplifiers for this purpose.

5.3.2 The calibrator includes provision for either manual control, holding any of the three calibration voltages at will, or an automatic mode of operation so stairstep sequences of 0, 2.5, 5, 0, 2.5, 5 volts may be generated indefinitely. For the "autocal" function, IC104 (MM74C901 hex inverter

chip) is used with two sections functioning as a clock oscillator at a frequency of approximately 10 pulses per second. The output of the clock oscillator, buffered by another section of the inverter, is taken from pin 5 as input signal to IC105, an MC14520B binary counter. Only the 1 and 2 outputs of this counter are used, to provide a recycle at intervals of three clock pulses. The 1 and 2 output buses (after inversion in two sections of IC104) are fed through IC103B, a 2-input OR gate, buffered and fed back as the reset pulse to the binary counter. The counting sequence is then 0, 2.5, 5 volts and reset to 0. Sections C and D of IC103 also are used in OR gate configuration to provide the desired control signals to the A and B inputs of IC106, an 8-channel multiplex chip. By virtue of enabling with only the 1 and 2 inputs, a recycle period of three counts (0, 1, 2) results. In the "autocal" mode, +10 volts is applied from the blockhouse control back to the data transfer switch, IC107, and the clocking action through the OR gates of IC103 establishes a steady state stairstep sequence. If the calibrator is placed in the manual mode by the associated control unit, a rotary switch permits selection of either 0, 2.5 or 5 volt calibration levels. The selected control voltage is then fed back through the umbilical to one input of the OR gate and IC103, to override the counter and establish a steady state condition for the multiplexer.

5.3.3 The transfer from data to calibrate mode is accomplished by the triple FET switches, IC107. When in the calibrate mode, control voltage is applied to the CD4053B switch in such a manner as to transfer data out of the telemetry system and substitute the selected calibration voltage selected by multiplexer IC106. If this voltage is removed (by removal of the umbilical, for example) the system is "fail-safe" and will automatically transfer to the data mode of operation, since it requires an external source of voltage be fed to the FET switch in order to remove the data from the VCO inputs. If calibration inflight is desired, it is necessary to provide a timer aboard the vehicle which can energize the control line to IC107 each time calibration is desired. This feature is not included in the breadboard model, but may easily be added when use is desired.

5.4 High-Speed Line Driver Development

In connection with the first flight tests of the MSMP payload on the TEM-1 flight, it became evident that a serious difficulty existed for checkout

of the payload while the vehicle was in the launch tower. The use of coaxial umbilical lines approximately 1000 feet in length from the actual vehicle to the associated GSE was causing severe problems with operation of the digital ground support equipment used for checkout of the payload. As an emergency field expedient, an operational amplifier line-driver was improvised for use in the launch tower, in order to drive the coaxial line back to the blockhouse. Although this permitted satisfactory checks of the system for launch of the first round, an obvious deficiency existed and thus an investigation was begun for selection of a suitable line-driver which could be included within the airborne coder in future versions, and which would have the capability of driving associated GSE. Desirable objectives here were supply of a flight component with modest enough power requirements not to compromise the prime battery power with idling current, and the capability of driving a 1000 foot terminated 50 ohm line with protection against damage to the instrument in event a short occurred within the umbilical line complex. The first (field expedient) amplifier required external power supplies and provided about only one-half volt drive at the blockhouse control station. A system was developed which would require minimum idling current, which could be supplied directly from the prime power aboard the vehicle, and still provided a driving signal of approximately 3 volts at the GSE at the far end of the terminated lines.

Bench tests of various available components immediately after the launch indicated that 1000 feet of coaxial cable could be driven by a commercially available component, but initial attempts with high speed operational amplifiers resulted in current requirements of as much as 0.5 amperes. Further investigation showed that the Burr Brown model 3329-03 hybrid integrated circuit power booster was usable for this purpose, and would meet the desired specifications. This unit can be powered from the ±15 volt buses used in the instrument, and consumes an idling current of approximately 15 milliamperes from this supply. However, when driving into a low impedance load, the peak current capability can be held to 100 milliamperes peak even in the event of a short in the associated cable complex (by a simple series 100 ohm resistor, internal to the instrument). The voltage divider action between the isolation resistor and the normal 50 ohm impedance of the cable results in approximately one-third of 10 volt output signal appearing at the GSE. Under normal conditions, with the 50 ohm impedance at the GSE end, peak power demand is approximately 65 milliamperes, tolerable during the checkout phase. After transfer

to internal power and removal of the umbilical system, power drain is reduced to the 15 milliamperes idle current (with an open circuit load condition).

As the first TEM-1 shot was a failure for recovery, the original version of the MSMP coder which did not include this line driver was lost. Buildup of the second unit incorporated the hybrid IC booster as an internal component within the encoder, thus eliminating this problem.

6.0 TRACKER AND TRAJECTORY EQUIPMENT

A large amount of work done under this contract period has been associated with Line Item 0001AD, the development of tracking through telemetry equipment as a follow-on to previous work under contract F19628-72-C-0139. In this portion of our work, both TRATEL I and TRATEL II trackers (constructed under previous contracts) were updated, in accord with more recent circuit developments. In addition, a new portable unit (called the Minitracker) was also developed, in a configuration which substituted a light-weight unit which could be dismantled for shipment in small shipping containers, compatible with convenient air freight shipment, and then assembled in the field. Total weight of the system was only a few hundred pounds, and no trailer mount was involved. A simple light weight pedestal riser with detachable legs and a demountable dish (which was sectioned for convenience in packing) were involved. Many components were similar to those used in TRATEL I and II, but a considerable amount of new circuitry was developed for this purpose. New design developments in the course of the Minitracker system development were then retrofitted into TRATEL I and II equipment, in order to improve operation. In addition, for ranging purposes the TRADAT I and II systems (developed under the earlier contracts) were also modified and updated in several respects. Evaluation of these systems was reported in Scientific Report No. 2 to this contract (Reference 11).

A serious fire at the Electronic Laboratory in May of 1977 resulted in virtual destruction of the tracking and trajectory equipment, necessitating a complete replacement. In the course of rebuilding the TRATEL equipment, more extensive changeover to the Minitracker-developed circuitry was used to provide more compact version. The external equipment for both Minitracker and TRATEL systems remain essentially as they existed prior to the fire; the interior electronics (for console control and operation) required complete rebuilding. After rebuilding, the tracking systems were designated as TRATEL IA,

AD-A062 472 OKLAHOMA STATE UNIV STILLWATER ELECTRONICS LAB F/G 4/1
ROCKET INSTRUMENTATION SUPPORT SERVICES.(U)
AUG 78 R F BUCK, R M FIKE, C M GWINN F19628-75-C-0084

UNCLASSIFIED AFGL-TR-78-0207 NL

2 OF 3
AD
A062472

TRATEL IIA, and Minitracker IA; the rebuilt TRADAT systems (which were also destroyed in the fire) were given the nomenclature of TRADAT III and TRADAT IV in order to avoid confusion with records involving the earlier versions.

Related work with trackers and trajectory equipment has also included extensive modifications to the AFGL (Canoga) tracker and the associated trailer in which its console electronics were located. This installation was modified at the OSU laboratory for use in support of the BAMM program. In the course of the modification, the Canoga tracker was converted for greater compatibility with the OSU TRATEL systems and, in some instances, to provide parts interchangeability with the Minitracker as well. At the same time, a PCM ranging system similar to the TRADAT III version was constructed and installed in the van, to add the ranging capability to the AFGL system.

One additional project would fall into the category of this equipment, but does not have autotrack capability. As a convenience to field operation, techniques similar to those employed in making the Minitracker more compact for shipment were applied to an AFGL 4-foot diameter manual tracking S-band receiving system. The system, as received from AFGL, was completely modified and new tripod build, the dish sectioned to permit more compact packing, and a preamplifier, intercomm, and AGC tracking indication equipment added. This system was completed and has since been used in support of several firings, where the trajectory capability was not required and manual track for telemetry data acquisition was sufficient.

6.1 TRATEL I and II Autotrack Antenna Systems

Two autotrack antenna systems had been built up at OSU (under previous contracts) for the purpose of acquiring data from airborne transmitters while the vehicles carrying such systems were in flight. These antennas automatically locked on to the source of radio frequency energy and would follow it in Azimuth and Elevation automatically, using a high-gain parabolic antenna, throughout the flight of the rocket. The systems were originally equipped with angular readouts which provided a bearing to the device being tracked, as well as providing a high-gain receiving link for the relatively low-powered transmitter-to-ground system. These systems were later combined with the TRADAT trajectory data system to add range data to the Azimuth and Elevation readout information, thus providing data for determination of the trajectory of the rockets. Both of the TRATEL systems were severely damaged in the fire;

although the exterior components were salvaged all interconnecting cables and interior control electronics (including the associated receivers, used for obtaining the error components for the auto track function as well as for data acquisition and recording) were completely lost. Both systems have been rebuilt since the fire and have been redesigned for a more compact configuration, making use of circuitry developed in connection with the Minitracker antenna (described in following section 6.2).

6.1.1 The original TRATEL I system was built under contract F19628-72-C-0172, and its configuration and operation was described in the Final Report to that contract. (See Reference 1, Section 4.6 for details.) The original TRATEL II system was developed and built up under F19628-72-C-0139, and was described in the Final Report to that contract; a comparison between the two systems was also offered in this report (Reference 6, Section 5.1, for complete details of this original system). The major differences between the TRATEL I and II systems consisted in the type of dish used for the 6' parabola concentrating received energy onto the RF head, and some minor details in servo amplifier components used to position the pedestal; these latter differences also occasioned a considerable difference in the interconnecting cabling, wiring, and power distribution. Both systems were originally constructed largely from components purchased from Scientific Atlanta Corporation, and a list of these components may be found in the above cited references 4 and 6. Exterior electronics included pedestal, servo amplifier, monoscan converter, and associated RF head controls.

Multiconductor and RF cables between the trailer mounted antenna proper and the interior electronics terminated in two relatively large cabinets, which included the basic Scientific Atlanta antenna positioning system, the displays and controls, and a modified DEI model TR-711 S-band receiver. The error signals in the original versions of both TRATEL models were developed from a Scientific Atlanta scan code generator, driving their monopulse converter and the associated phasing hybrids, all located within the RF head. Monopulse techniques were then used from the array of antennas inside the feed to develop associated position error signals within the Scientific Atlanta converter. Prior to the fire, both TRATEL systems had been modified to utilize the OSU/Vectronic monopulse converters which were developed under this contract (described in Scientific Report No. 1 to this contract, Reference 7). The replacement was made for economy, simplicity, and greater reliability of the

system; the basic system so developed was retrofitted into the Minitracker described in a later section in this report, as well as to the existing versions TRATEL I and II. Experiences with bitter cold in the Artic environment in which these were sometimes used also resulted in the incorporation of a pedestal heater and control system, in order to improve operation of the RF feed and antenna positioning system in cold weather.

6.1.2 After destruction of the interior electronics, the decision was made to rebuild TRATEL into a more compact configuration and update circuitry to take advantage of circuits which had been developed at OSU under this contract in connection with the portable autotrack antenna, the Minitracker. Because both systems were heavily committed to field support activities in connection with several forthcoming programs, notably the BAMM series of flights, the rebuilding was accomplished under emergency conditions and maximum usage was made of existing printed circuit negatives and modular subdesigns which had been developed for the Minitracker. This resulted in the elimination of many of the original chasses in the overall system, and the reconstructed interior control consoles electronics are as depicted in Figure 10. The overall interior electronics now consist of only three pieces of equipment, which occupy less space than one of the two consoles required for each system in the original version. For either version of TRATEL, interior control electronics now include one Scientific Atlanta S-band receiver (from their series 410WA models, supplemented with appropriate tuners, IF filters, and demodulators). The major operating console is OSU-built for each system, and is supplemented by a single Scientific Atlanta component, the SA model 1840 dual digital synchro display unit with offset controls, which permits display of the Azimuth and Elevation pointing angles and controls for offset of the displayed angles (to compensate for the actual siting of the trailer-mounted pedestal, with respect to any local coordinate system). All components for the main operating console are combined into the single OSU-constructed system.

6.1.3 The consoles differ slightly. The TRATEL IA console is as shown in OSU drawing D95BC01A; the TRATEL IIA console is OSU drawing D95GC13. The consoles are identical in overall dimensions, measuring 17.8 centimeters in height by 43.2 centimeters in width by 44.5 centimeters in depth. Panel controls and displays are also identical. Each is equipped with three analog meters. One displays an indication of the received signal strength, derived from the AGC of the associated Scientific Atlanta model 410WA receiver. The

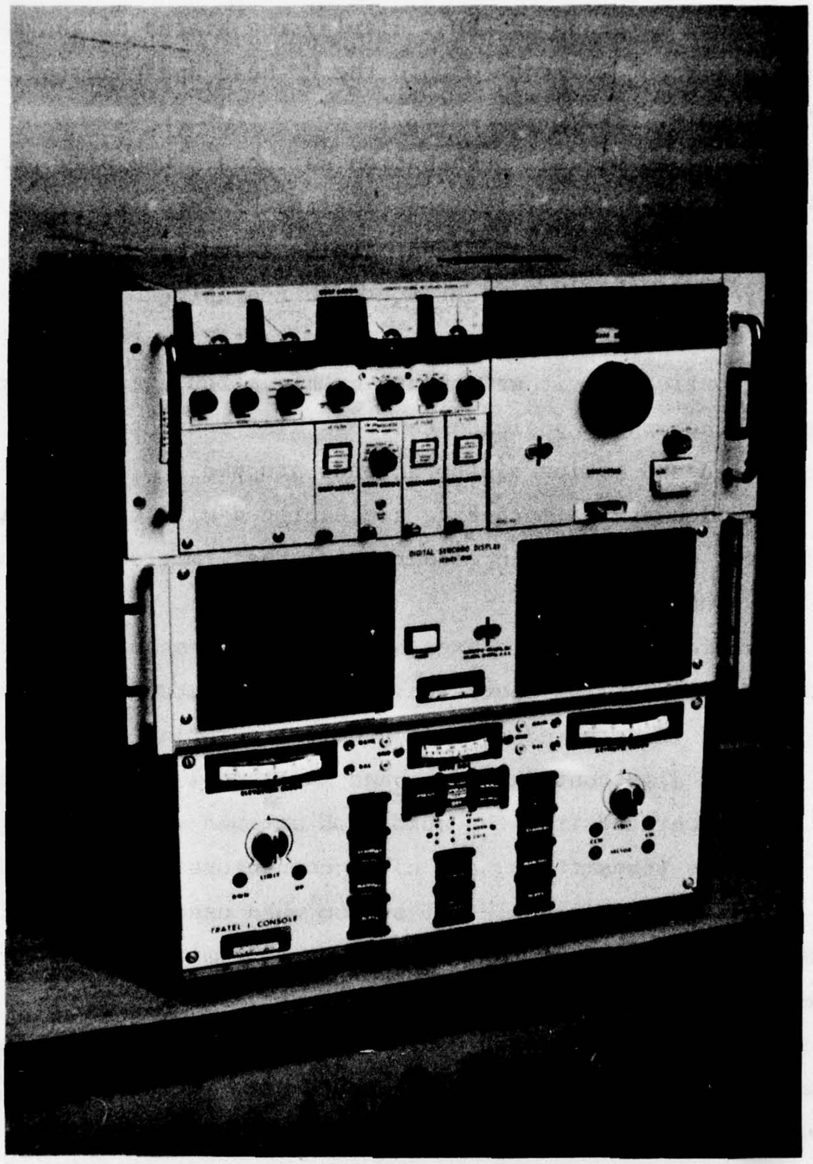


Figure 10. TRATEL IA, Interior Electronics

other two meters display the Azimuth and Elevation error signal within the servo control system, and are used both in set-up and as an indication of tracking accuracy. A group of LED's display the status of the temperature and the heater control elements within the RF head and pedestal, exterior to the control console.

Controls include several push button switches. One will permit transfer from the "Operate" to "Calibrate" mode for the RF feed (RF preamp in, or bypassed within the RF feed). A second permits Azimuth sensing as either "normal" or "reversed" with respect to angle convention. Since no slip rings are contained within the pedestal, but limit switches are provided to avoid damage by overcontrol in either Azimuth or Elevation axes, a pair of display lights beneath the manual position controls also indicate when a limit switch has been actuated and motion of the antenna stopped.

Both Elevation and Azimuth axes are equipped with knobs to permit manual rate control of position in either axis; the limit switches are below the corresponding control knob.

Both Elevation and Azimuth axes have lighted pushbutton switches, to permit four different modes of operation: autotrack, standby, manual control, and slave control (from an exterior source for pointing information).

Each console also contains an S-band Multicoupler, permitting additional receivers to be operated from the autotrack antenna when tracking a vehicle with more than one transmitter, and cable connectors are provided for proper interface with the associated TRADAT system when used in the full trajectory determination mode, in order that Azimuth and Elevation angle information may be inserted with the other data required by the TRADAT system.

Differences between the two consoles are minor and caused largely by the difference in the servo amplifier components used in the exterior pedestals. The TRATEL IA console has incorporated two electronic cards for the Scientific Atlanta model 3621 servo amplifier, which are not required for the TRATEL IIA version. Also because of the differences in the servo amplifier, there are minor differences in the control cable interconnections between console and external pedestal. Although an attempt was made to establish compatibility with external cabling for TRATEL IA, TRATEL IIA, and the Minitracker versions of the systems, these differences have so far prohibited convenient retrofitting for identical cabling and connector pin allocations. Printed circuit cards used throughout are essentially identical; the Minitracker cards

are used wherever possible within the TRATEL IA and IIA consoles. Each console also includes internal power supplies, operable from 115 volt 60 Hz single-phase power, to generate all required dc operating voltages. The console serves as a power distribution and control system, with internal relays controlling operation of the external pedestal by cabling from console to the external trailers.

6.1.4 A full description of the Minitracker console is included in Appendix A to this report. Reference may be made to the appendix for a more complete discussion of the operation of the console for the TRATEL system, which is quite similar to that of the Minitracker.

Modes of operation for each axis are identical. When power is first turned on, the console is automatically placed in the "standby" mode in both Azimuth and Elevation. In this mode Azimuth and Elevation brakes are engaged in the pedestal, and all power is removed from the drive motors. Pushing the "manual rate control" button transfers the system to the manual mode, in which the antenna position may be slewed by turning the manual rate knob. This mode of operation simply provides positive or negative voltage to the associated power amplifier in order to reposition the pedestal in the desired direction. When transferred to the "autotrack" mode, the error signals are derived from the autotrack error signals generated from the monopulse converter; the pedestal automatically repositions itself so as to drive both error signals to the null mode.

Other operating controls are self-explanatory. The RF feed may be transferred from the "operate" to the "calibrate" mode with a panel control which simply transfers a coaxial relay within the RF feed, replacing the antenna cable to the system with a cable from the pedestal back to a signal generator, thus permitting calibrated signals to be introduced for AGC calibration. Preamplifier control is also self-explanatory, in that the two modes either energize the amplifier, or bypass the preamplifier, within the RF head. The Azimuth "normal/reverse" switch simply inverts the sense of the Azimuth signals to permit clockwise or counter-clockwise convention. This feature is included as a convenience in setting up and calibrating the system, when the "plunge and rotate" test is used in the field to establish proper set-up of the tracker angular references.

The "slave" mode of operation is also available in either axis, but requires a proper interface chassis external to the console. (This feature has

been provided for future use, wherein one tracker may be slaved to pointing angle information from some other source.)

Operation of the TRATEL system is quite similar to that described in Appendix A for the Minitracker. A scan code generator (OSU card B95DC06) generates the proper driving signals to the associated monopulse converter, located within the RF feed. It also provides synchronization signals to the demodulators for each axis, built on OSU printed circuit module C95DC05. However, in the TRATEL consoles a unique card (OSU model B95CC14) is used in conjunction with these demodulated signals, to provide compensation and amplification control for the error signals. These compensation cards consist of an operational amplifier which processes the raw error signal from the demodulator prior to applying it to the servo amplifier. Amplitude-sensitive feedback networks around the operational amplifier modify the gain in accord with the amplitude of the error signal, thus modifying the servo speed of response to achieve smooth and accurate tracking.

The console-mounted sine-cosine converter is a purchased component, Computer Conversions Corporation model SD103P, and is identical to that used in the Minitracker. This portion of the console takes the 90 volt 60 Hz synchro resolver signals from the Aximuth-Elevation angles of the tracker and converts them into dc voltages, proportional to the sine and cosine of the angle displacement indicated by the resolver. A divider card (D59DC04) also permits these voltages to be used to provide correction voltages to the Azimuth gain as a function of the Elevation angle, to improve tracking accuracy at high elevation.

The manual command card (B95DC07) is identical to that described for the Minitracker. Identical cards are also used for the heater monitor and control circuit, OSU C95BC03.

6.2 Minitracker

The Minitracker system was designed under Line Item 0001AD to this contract, which called for development of a portable system for acquisition of data and tracking through telemetry, for specific use at remote launch sites where fixed-site telemetry reception is not normally provided. Although originally conceived as a data acquisition device only, capable of locking to a moving source of S-band data and continuously tracking in Azimuth and Elevation for data acquisition purposes, it was soon obvious that the flexibility

of this system could be extended by using it in conjunction with the TRADAT system for trajectory data purposes.

The system so developed was very small and consists of a servo-controlled 4-foot diameter parabola with suitable RF feed and control electronics, as illustrated in Figure 11. One of the objectives was a system which could be dismounted into a number of small shipping containers which could conveniently be shipped to remote sites. Each shipping container was to be kept small enough to permit convenient handling and one-man assembly in the field. The final system which was developed for this purpose breaks down for shipment such that no one component has a net weight of over 100 pounds. When crated for shipping, a total of seven shipping containers with a gross weight of 679 pounds result. Volume of the system, packed for shipment, is only 48.7 cubic feet, and it can readily be air-shipped, since no one container is larger than 12 cubic feet in volume. Shipping dimensions were carefully chosen to insure compatibility with cargo hatches for conventional aircraft. A view of the Minitracker console with the cover removed is shown as Figure 12. A complete manual describing the current version of the Minitracker and giving operating instructions is included as Appendix A to this report, and may be referred to for greater detail.

6.2.1 External components of the assembled Minitracker consist of a pedestal with a small Azimuth-over-Elevation servo-driven positioning system, on which is mounted a 4-foot parabolic dish and the associated RF head, which contains the monoscan converter to develop the error signals for autotrack action. Total weight of the exterior electronics when assembled is 296 pounds; when disassembled, the heaviest subassembly is the pedestal riser section which weighs 90.5 pounds. Three legs spaced 120° support the riser mechanism, and each is equipped with a screw jack for leveling. A circular bubble level is visible through a plexiglass window on top of the head assembly. The pedestal riser also includes the power amplifier for driving the servo systems. The Azimuth-Elevation head includes drive motors, gearing, tachometers for feed-back, limit switches, brakes, heaters, and synchros for indication of the pointing angles. Maximum slew velocity is 30° per second, with a maximum acceleration of 100° per second^{2}; pointing accuracy is specified at $.075^{\circ}$ RMS on either axis.

6.2.2 All necessary controls and monitors for operation of this system are contained within a single console, similar in configuration to that

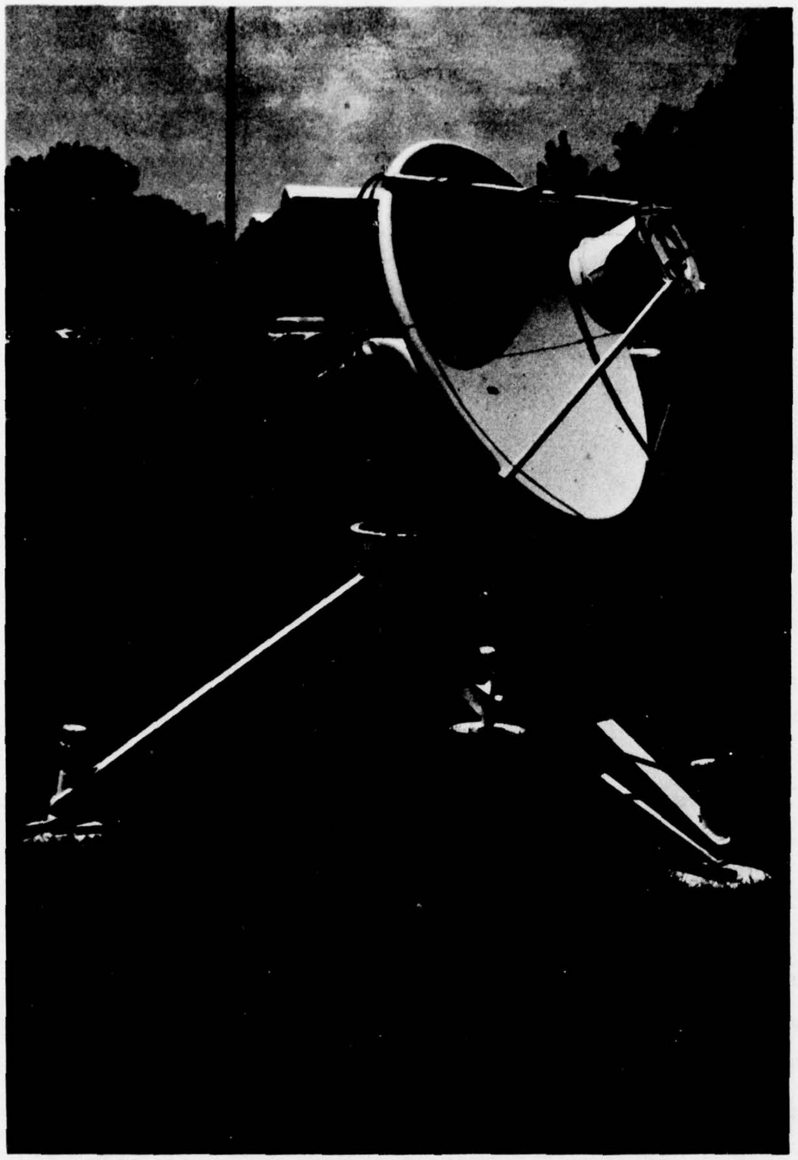


Figure 11. Minitracker Antenna and Pedestal

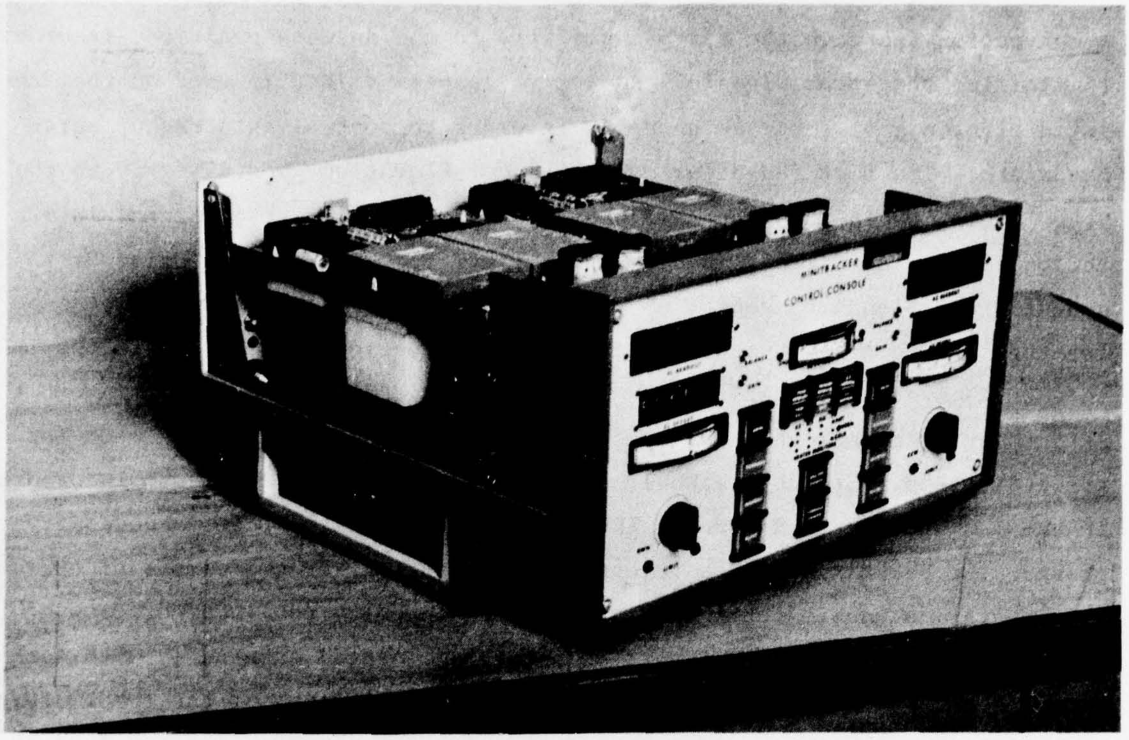


Figure 12. Minitracker Console

described for TRATEL in the preceding section. The console is slightly higher (22.2 centimeters vs. 17.8 centimeters for the TRATEL system) with the same width and depth. (Additional height was necessitated by incorporation of the digital angular displays and offset switching mechanism as a portion of the Minitracker console, whereas a separate chassis was used for the TRATEL IA and IIA versions.) Operational modes and controls are the same as described for TRATEL autotrack systems.

A scan code generator within the console provides synchronized driving signals to the monopulse converter which is located within the RF head, and also provides reference signals for demodulation of the error signal (which is received in the form of an amplitude modulated wave train from the RF head). The amplitude modulated RF signal from the RF head is fed through the Azimuth and Elevation demodulators to develop error signals for each of the channels. Each channel of the error signal detector compares the amplitude modulated composite signal from the RF head with the scan code generator reference signals and derives an error signal of the proper polarity to apply

a correction (through the servo amplifier) to the antenna position, in order to minimize the error signals. An active lowpass filter is used on the demodulated error signal for each channel, in order to control autotracker servo bandwidth. The filtered dc error signal for Elevation goes directly to the power amplifier in the pedestal, whereas the Azimuth dc error signal is run through a special circuit in order to correct the error signal drive by an amount proportional to secant of the Elevation angle in order to compensate for the loss in Azimuth sensitivity at high Elevation angles. As in the TRATEL IA and IIA systems, an Azimuth Normal/Invert switch can be used to invert the Azimuth error signal when the tracker is in the plunge and rotate mode for tracker set-up. Standby, manual, and slave modes of operation are incorporated in the manner described for the TRATEL IA and IIA systems; it is necessary to provide the proper interface to operate the Minitracker slave mode of operation.

Operation under Arctic conditions is assisted by the incorporation of four sets of thermoswitch sensors and heaters, located externally within the pedestal and RF feed. Each provides an analog indication of the temperature at that location by means of a thermistor circuit. Analog voltages from these circuits enter voltage comparator circuits within the console which operate indicator lights to show whether the temperature is too high or too low for normal operation. The circuit also automatically energizes stripheaters, in order to correct if the temperature is too low by raising the local temperature to the proper operating point.

Angular readout of Azimuth and Elevation angles is provided from synchro to BCD converters and digital offset circuits. Data Device Corporation Model SR103 units are used to convert the synchro signals into binary-coded decimal form. The BCD output can then be run through the offset switches, in order to permit Azimuth and Elevation angle readouts to be adjusted relative to true North and Horizontal reference directions. (Offset data is simply added, with proper polarity, to the binary-coded decimal angular data from the converter; the digital display unit then reads the proper corrected angle for each axis.)

Complete details of the methods to be used in assembly and operation of the Minitracker system are included in Appendix A.

6.2.3 The original version of the Minitracker was damaged severely in the May 1977 fire, and the interior control console was completely destroyed. The system has since been rebuilt and is now designated as the Minitracker IA system, in order to distinguish between the rebuilt version and the original

system. Both original and rebuilt (IA) versions of the Minitracker have been used in a number of support missions during the course of this contract. Provision has been incorporated on the Minitracker pedestal for addition of an antenna to radiate the upleg ranging signal from an associated TRADAT system by permitting use of the Minitracker to point the low frequency antenna toward the vehicle being tracked.

6.3 TRADAT Systems

A system for trajectory data determination, in conjunction with autotrack antenna systems, was developed and named "TRADAT" under previous AFGL contracts. The original version of this system was developed under F19628-72-C-0139 as a prototype PCM ranging system (Reference 6, Section 5.2.3). The prototype system was later developed into the TRADAT I trajectory system under contract F19628-72-C-0172 (Reference I, Section 4.7). A duplicate of the TRADAT I system was then developed under the nomenclature TRADAT II in early work under this contract. Both TRADAT I and II systems were destroyed in the May 1977 fire; the only component salvaged was time code generator from the TRADAT II system, which had been removed and was not within the console at the time of the fire.

6.3.1 The basic TRADAT system develops trajectory data for the vehicle being tracked by use of range data, supplemented by Azimuth and Elevation pointing angles from the tracking antenna. This polar coordinate data may then be used to generate the desired trajectory elements. Operation starts with generation of a special PCM coded signal, synchronized with a "start" pulse to a time interval counter. The PCM code modulates an uplink transmitter whose antenna is slaved to the S-band autotrack antenna for position. The uplink ranging code is received by a receiver aboard the payload and retransmitted on the standard telemetry downlink, where it is received from the autotrack antenna as a portion of the telemetry reply signal. This is normally in the form of a low frequency PCM modulation of one VCO within the IRIG FM/FM analog telemetry used on the S-band down link. The video from the telemetry receiver is then fed through a suitable FM discriminator to retrieve the PCM modulation, processed through a bit synchronizer, and a PCM code detector circuit is used to generate a "stop" pulse for the interval counter. The time between "start" and "stop" is then proportional to the loop range and, by suitable choice of the time interval counter base, may be made to read

directly in kilometers.

The range in kilometers, together with the Azimuth and Elevation angle from the pointing antenna, are then fed (in binary-coded decimal form) into a data coder, which mixes in the time code for the measurement (also in BCD form) and generates a 1000 bit per second PCM data stream which includes a frame synchronization group, followed by the range time (in hours, minutes, and seconds to nearest 1/10th second) the Elevation and Azimuth angles (to the nearest 0.01°), the range (in kilometers to nearest 0.01 kilometers), and some monitor data concerning the mode in which the tracker is operating. This low speed serial PCM train may then be used to modulate a voltage-controlled oscillator in the station multiplex system and be recorded on magnetic tape, together with the telemetry data from the same flight.

The associated decoder within the TRADAT system permits the serial stream to be decoded and processed, either in real time or through playback of the magnetic tape. The system is normally interfaced with a digital printer to provide a printout of the information, sometimes with the slant range converted to altitude and ground range components as well.

Two new TRADAT systems were built up after the fire, to replace the TRADAT I and II equipment which were destroyed.

6.3.2 The two new systems built up late in this contract were designated as TRADAT III and IV systems, to distinguish them from the earlier versions destroyed in the fire. A photograph of the new system is shown in Figure 13, with the associated digital printer. Circuitry used essentially duplicated the original equipment; minor modifications were made by changing the low speed serial PCM data train from NRZ-Level to Biphase-Level form, to facilitate playback and processing. Minor changes were also made in the bit synchronizer, to reduce residual range jitter. The 430 MHz transmitter used for the uplink was completely replaced with a new design, using a commercially available 2-watt transmitter as the exciter for the same power amplifier equipment used in the original version. The feature of a monitor for both direct and reflected power was retained, but the OSU constructed modulator, exciter and deviation monitor portions of the original transmitter were deleted in the replacement.

As rebuilt, each of the TRADAT systems consists of the following components: one Datum model 9300 time code generator/translator, one General Radio model 1192B interval counter (modified for time base, to read direct in

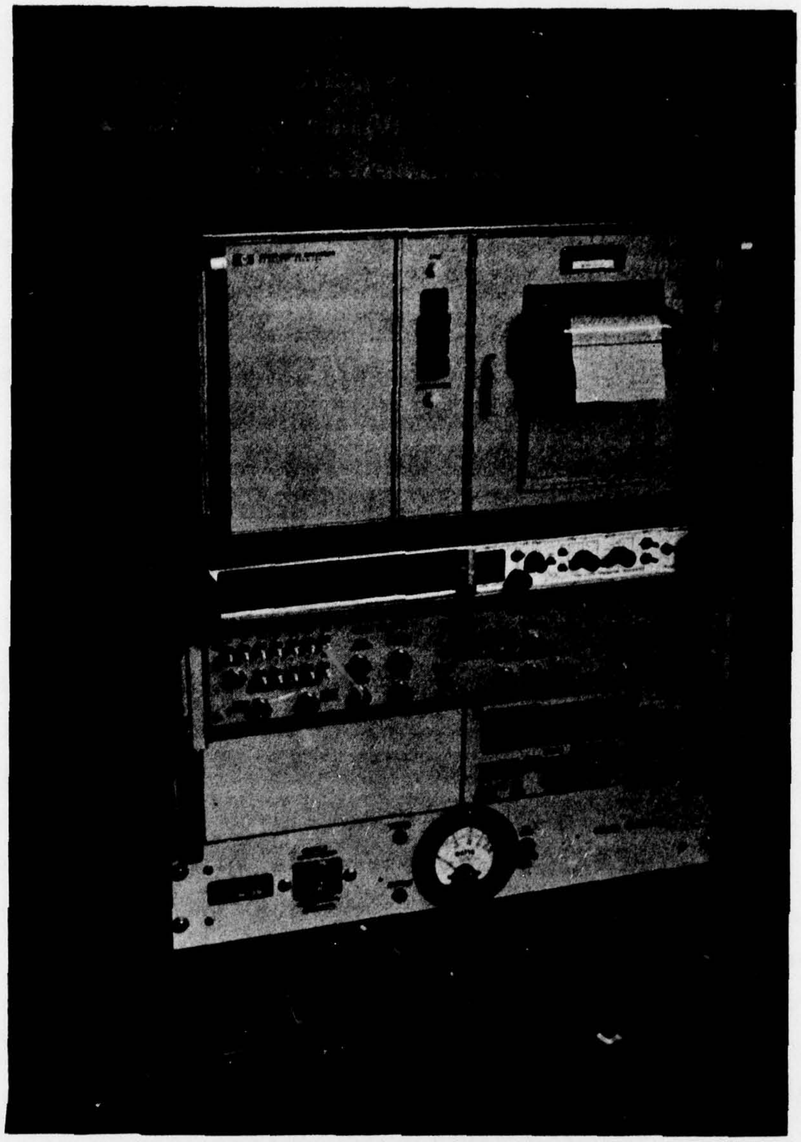


Figure 13. TRADAT III System
(With H-P 5050B Digital Printer)

kilometers range), one OSU model C95FD01 PCM trajectory chassis; and one ranging transmitter, OSU model B95RF01. The uplink transmitting antennas remain model D35ET01, described elsewhere in this report and developed previous to the fire. (These antennas were not damaged, as they were not within the building at the time of destruction.)

6.3.3 Uplink transmitting antennas were developed specifically for the TRADAT systems under this contract. The final model was designated as OSU design D35ET01. A four-turn helix, operating against a ground plane reflector, provided right-hand circular polarization, with a three DB beamwidth of approximately 50° and a circularity of polarization of $\pm$ 2 db with respect to true circular. The VSWR varies slightly with the individual antenna match, but is approximately 1.3:1 for a well-matched antenna and in no case worse than 1.8:1. The antennas are mounted on a aluminum tube as a beam support, which may readily be attached to the associated S-band autotrack receiving antenna so as to follow the same pointing angle. Power handling capability is in excess of 100 watts. A total of six such antennas were built. Three were retained for local use, and three others delivered to AFGL for use in support of the BAMM program.

6.3.4 The original version of the ranging transmitter, used in TRADAT I and II prior to their destruction, has previously been described in the final report to F19628-72-C-0172 (Reference 1, Section 4.7.4). Deployment of this early model of transmitter in the field resulted in difficulty in connection with the series of White Sands test launches, in which the transmitter deviation was inadvertently set too high for compatibility with the associated airborne receivers. As a result, a development program was initiated to provide an indication of the transmitter deviation for field checks and adjustments. The deviation monitor shown in OSU drawing C95ER06 was developed for this purpose and installed in all existing transmitters prior to the fire. (As noted above, this deviation monitor was applicable only to the OSU-constructed transmitters, and is not included in the version in use at the present time.)

The deviation monitor consisted of the simple down-converter which used a voltage-controlled local oscillator and balanced demodulator to derive a 30 MHz translated output signal, within the transmitter. The RF input signal was picked up by use of an input cable, dressed in close proximity to the output cable from the associated ranging transmitter. The internal local oscillator, operating at a frequency of 460 MHz, was provided with a trim

adjustment for tuning and, through the balanced modulator, developed an intermediate frequency output with the center frequency adjustable over a small range by trimming the voltage applied to the local oscillator. This 30 MHz signal was brought through a monitor jack on the panel of the transmitter and could be used as 30 megacycle input signal to the associated DEI model TR-711 receiver. The voltage adjustment was crudely calibrated to indicate deviation from the assigned center frequency when each deviation monitor was installed; the pointer on the adjustment knob indicated, on a hand drawn dial, the approximate deviation from assigned center frequency and served as a rough check of frequency stability in field operations. The internal deviation monitor meter of the DEI 711 receiver was used to display the transmitter deviation in the test mode. Operation consisted of connecting a jumper cable from the modulation monitor jack to the 30 MHz input of the DEI receiver, trimming the frequency adjust control on the ranging transmitter to indicate a zero discriminator center reading on the receiver. The deviation could then be read directly from the TR-711 receiver. A total of four such deviation monitor circuits were constructed and installed in the ranging transmitters provided for the original systems. (Each of these systems was equipped with both 403 and 430 MHz transmitters, to permit use in a proposed overseas operation prior to the fire.) A fifth deviation monitor was later constructed and added to the ranging system installed in the AFGL tracking system, as described in section 6.4. This latter unit is the sole surviving version of the original transmitter design with deviation monitor installed.

6.4 AFGL (Canoga) Tracker Modification

The AFGL-owned autotrack S-band antenna, originally procured from Canoga, was also modified during the course of this contract. In this system, the antenna pedestal and servos are mounted on a trailer (registration number HNX00267) and the associated console and control electronics are located in the corresponding instrumentation van (registration number 52X0021). Originally, only the instrumentation van (containing the control electronics) was shipped to OSU for the purpose of modification and additions in conjunction with readying the equipment for support of the BAMM mission. The overall van conversion activities are described in section 6.7 of this report. Certain portions of the initial work were associated with the tracking equipment and were accomplished prior to the BAMM mission. Further difficulties were encountered

with the Canoga tracker during the BAMM mission, and both antenna and control electronics were returned to OSU for additional modification.

6.4.1 The first modifications of the Canoga tracker were made for the purpose of adding TRADAT-type trajectory capability to the existing autotrack antenna. The prototype PCM trajectory system, developed under contract F19628-72-C-0139, was updated to the TRADAT configuration (with the exception of the time interval counter, which remained GR-1191 version) and then installed within the same rack as the antenna positioning control system. To make this installation required some relocation of mechanical components within the Canoga control system, and rewiring the 110 volt 60 Hz prime power distribution system for compatibility with the required load distribution and power control circuitry.

6.4.2 At the time of this installation the associated tracking antenna was not available, but the modified TRADAT system was installed and some difficulty was encountered in interfacing the angular readout of antenna position with the TRADAT encoder. The original Canoga angle indication was by means of optical pick-offs for shaft positions; these were incompatible both with the sense desired and coding required for inputs to the TRADAT coding system. As a result, AFGL had already installed some code-converter circuitry to provide signals in the 1, 2, 4, 8 BCD format required on both axes. Interfacing cables were prepared and the system checked with a simulation of the actual pedestal, which was not available at the OSU laboratory.

6.4.3 During the BAMM support mission, continued difficulties ensued with erratic readings for the antenna position, and unreliable operation. As a result, the Scientific Atlanta model 1840 digital display unit was removed from the TRATEL IA system and installed, as a field expedient, to convert the synchro resolving data to the required format for interface with the TRADAT equipment. This improved reliability and satisfied the requirements. AFGL has since arranged to replace this original Canoga circuitry with the Scientific Atlanta equipment and will return the loan unit from TRADAT IA system.

6.4.4 At the conclusion of the first BAMM mission, the antenna trailer was returned to the OSU laboratory for further modification and repair work. The associated control electronics were also removed from the instrumentation van and sent to OSU with the trailer, to permit further revisions at the OSU facility.

The RF feed supplied with the parabola for the Canoga tracker utilized an

antenna array which differed substantially from the Scientific Atlanta version, which was in use in all the OSU autotrack equipment. A more complex antenna array with both left-hand circular and right-hand circular polarization outputs and a multiplicity of preamplifiers and RF cabling was involved. This RF head was removed from the Canoga dish and an attempt to modify it for closer compatibility with the OSU version was made. All RF phasing lines, RF combiners, etc. were removed from the Canoga head and the entire cabling system changed to establish compatibility with the standard Vectronics MC2223MDA monopulse converter which is used in the Minitracker and TRATEL equipment. The coaxial relay used for the operate/calibrate mode and standard Avantek preamplifier, exactly as used in the OSU version, were also installed in a new physical housing, whose mounting was made interchangeable with the Scientific Atlanta Model 72. This configuration was devised in hopes that the Canoga head could be rendered mechanically and electrically compatible with other S-band heads available within the support complex. Although operation was achieved with the modified unit, it was inferior to that from the Scientific Atlanta version, and exhibited large crosstalk components, with Azimuth errors creating false errors in the Elevation channel, and vice versa. As a result, the recommendation was made that this approach be abandoned and that the head be changed to the S/A model 72. This project is now under way, with components removed from the modified Canoga head being used for completion of the SA 72 head in the desired configuration.

At the same time, the control electronics were overhauled and maintenance performed in order to give reliable and improved operation from the Canoga system. By using both the borrowed digital display and a borrowed 72 head from the TRATEL IA system, the Canoga system was placed in operational status, permitting further support use.

6.5 S-band Manual-Track Antenna

During the course of this contract, it became evident that there were a number of support missions in which autotrack capability was not required and a simple manual tracking receiving antenna would suffice for checks and back-up coverage. AFGL already possessed the components for preparation of such a system: a 4 foot diameter Andrews parabola equipped with a special circular polarized helical feed from Physical Science Laboratory of New Mexico State University, together with the manual Azimuth-Elevation head and folding tripod

assembly. This was supplemented by a rack-mounted multicoupler and a rack-mounted power supply control unit for a remotely located (at the RF head) S-band preamplifier, both manufactured by Locus, Inc. This system had been used in support of several missions, notably at the PFRR facility in Alaska, but had proved difficult to handle from a logistic standpoint, inasmuch as the disassembled dish and associated cable required a shipping container approximately 5 feet square and 1 foot thick, and the remaining components, including the tripod, were packed in a large shipping canister approximately 2 feet square and 6 feet long. Both were awkward for easy shipment by air. OSU was asked to modify this system to a more convenient configuration for field support and, at the same time, supplement it with a redesigned electronics system permitting intercom capability (previous installations utilized radio handy-talkies for communication between operators), some provision for calibration of the link, a tracking meter, and preamplifier power control. The system which was developed for this purpose is depicted in OSU drawing C38GA01. It is shown in Figure 14.

6.5.1 The first step was one of mechanical revision of the components to permit easier shipment. The 4 foot dish was modified by removing two chord sections, diametrically opposed, so as to permit shipment in a container whose cross-sectional area was only 27 inches by 51 inches (this is the same container used for shipping Minitracker components). The antenna was attached to hand formed C-cross-section doublers, then equipped with stainless steel threaded blocks and stainless steel hardware for assembly and disassembly without corrosion of the attaching parts.

The next step was a similar modification of the supporting tripod. Legs were shortened and equipped with a telescoping section to permit the three captive tripod legs to be folded together and telescoped to fit within the same length, yet permit extension to a convenient height for manual track. The original adjustable head with Azimuth and Elevation pivots and a single clamp for locking the array into position was retained. Since the feed was already short enough in length, this put all major mechanical parts in a configuration capable of fitting within the standard molded shipping container used for the Minitracker. It is shown, disassembled for shipment, in Figure 15.

6.5.2 The Locus model RF 499B preamplifier and model MC163A multicoupler were next completely disassembled from their rack and panel mount configuration,

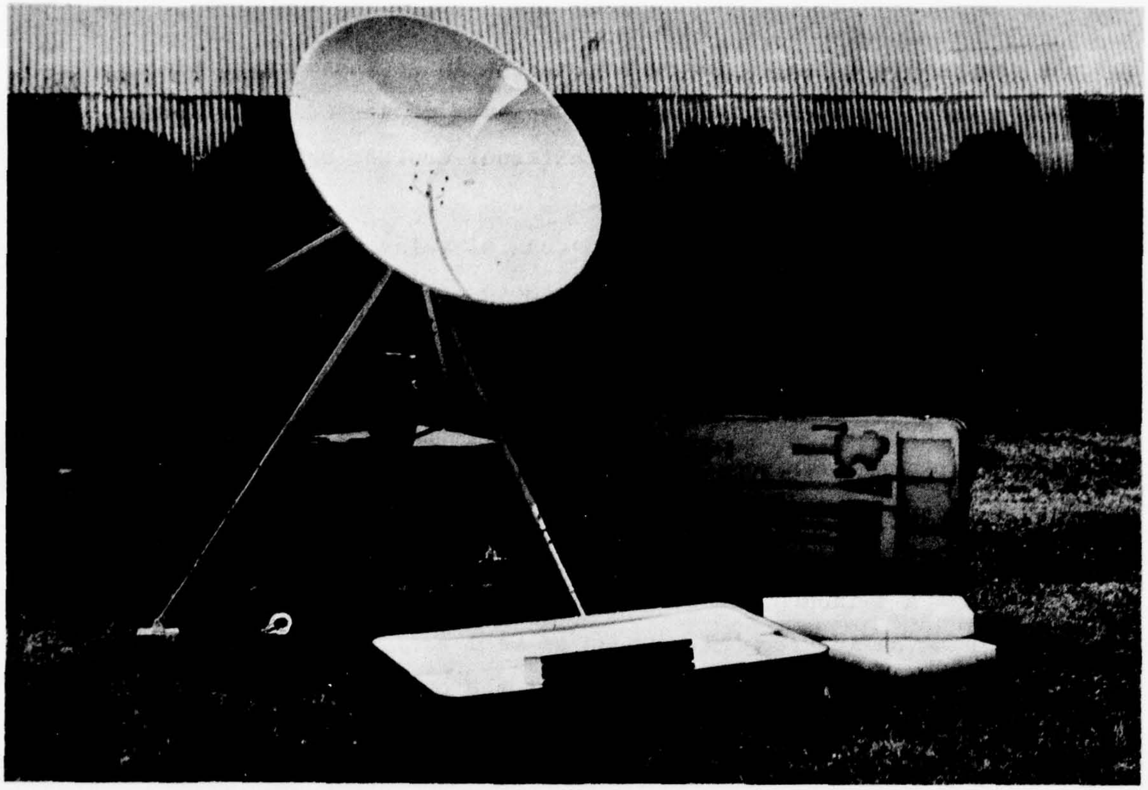


Figure 14. S-Band Manual Track Antenna

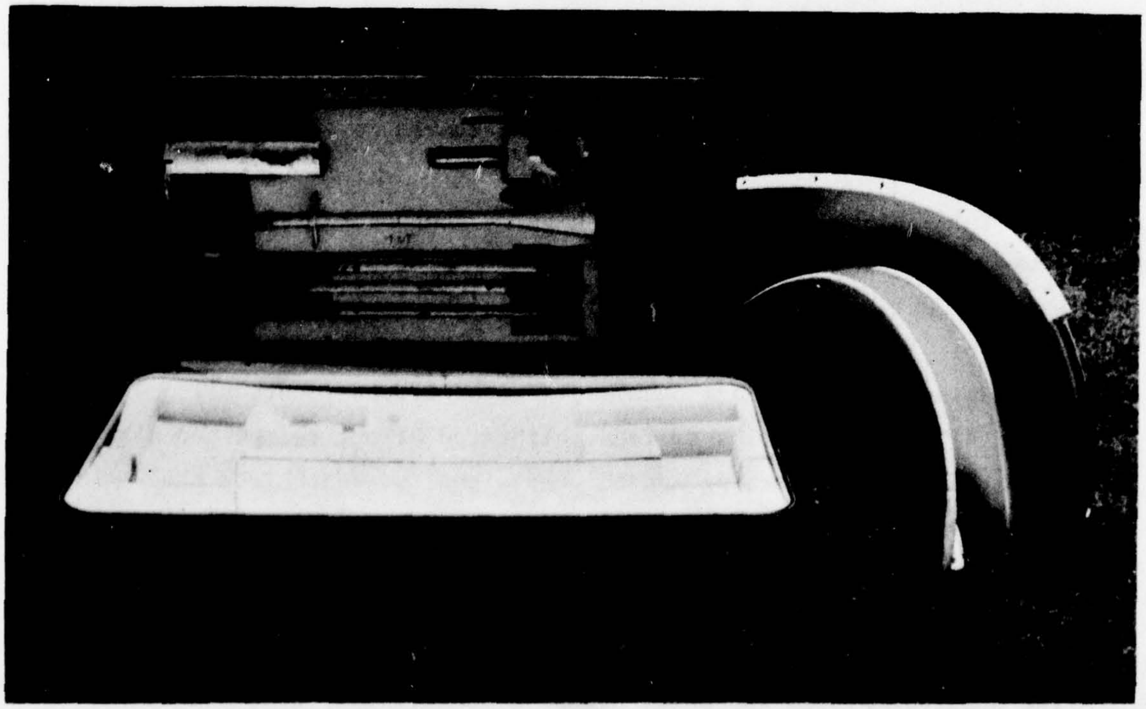


Figure 15. Manual Antenna, Packed for Shipment

and the components salvaged for incorporation in the associated electronics for this system. A small weather-proof box was constructed and arranged to mount on one leg of the tripod. This external monitor box includes the following items:

(a) Transco Model 910C30200 coaxial relay (to permit transfer from operate to calibrate mode by remote control from the blockhouse section).

(b) The Locus Model RF499B preamplifier, with internal 110 volt AC power supply. (The output of the RF relay is connected directly to the preamplifier, whose output is then fed back through foamflex cable to the internal control section. The preamplifier is energized from the main AC power system within the blockhouse.)

(c) A 3-inch speaker, with a push-to-talk switch permitting its use as an intercom microphone as well as a speaker. (External volume control is provided, to permit the operator to adjust the volume of the signal received from blockhouse control section.)

(d) An illuminated 50 microampere meter with a polarity reversal switch and sensitivity control (for use as a remote AGC meter, indicating the strength of the signal being tracked).

An internal operator's control box was also constructed, for installation within the blockhouse station which normally is used with this support capability. The internal control box contained the following:

(a) Power supply (to supply the required dc voltages for operation of the system).

(b) The Locus MC-463A multicoupler components (permitting four independent isolated outputs from the RF feed, through the external calibration relay and preamplifier combination).

(c) Audio intercom amplifier and monitor speaker (for communications between blockhouse and antenna tripod location).

(d) Coaxial cables to feed calibrated RF out to the pedestal from the signal generator and to feed signal strength from the associated receiver AGC to the external system.

Operating controls consisted only of the operate/calibrate switch (to transfer the preamplifier from a calibration signal generator to the antenna), and the gain controls for the audio amplifier system.

The intercom system was built around a commercially available 3-watt

system, Calectro model J4592, modified with appropriate input transformers, gain controls, and a monitor speaker. Wiring was so arranged as to leave the audio from the operator's control to the remote antenna tripod operating, unless overridden by a push-to-talk switch by the man tracking outside the building. The remote push-to-talk switch transferred amplifier connections by means of relay within the console, and permitted two-way conversations when desired. The entire system was interconnected by a multiconductor cable which incorporated 9 power and control leads, a shielded audio lead, and 50 ohm coaxial cable. Standard 115 volt 60 Hz ac power was also available from a duplex receptacle at the pedestal position whenever the system was energized, for auxiliary equipment which might be required at the operator's position.

6.5.3 Both monitor box and control box, all connecting cables, the antenna and feed and tripod were all arranged with foam cradles to mount in the shipping container which was extended from its normal 16 inches height to 21 inches. This permitted the entire system to be packed in the single container of only 15.5 cubic feet, with a shipping weight of approximately 170 pounds. Container dimensions are such as to permit shipment through the cargo hatch of most commercial air services. The system has been successfully employed in support of a number of missions since modification.

6.6 Auxiliary Tracking and Trajectory Equipment

A number of auxiliary items of equipment have been provided in connection with the tracking and trajectory work. These include: digital printers for convenience in printing out either real time or playback data on trajectory elements from the TRATEL/TRADAT systems, small balloon-borne S-band sondes were built for set up calibration and test of the tracking system, and a dedicated microprocessor for conversion of trajectory data to more convenient form.

6.6.1 The original version of the trajectory data system was designed to be operated in conjunction with the Hewlett Packard model 5050B line printer. Details of this operation were reported in the final report to F19628-72-C-0139 (Reference 6, section 5.2.3.3). Two such printers were provided and interfaced with the original TRADAT I and II equipment. In addition, an Anadex model 650 digital printer was obtained early in this contract and modified for use as an auxiliary printer with this and other data systems. It was intended that the Anadex printer be used with the Minitracker when operated in the full trajectory mode, since it was lighter in weight, more compact, and required

less power than the Hewlett Packard equivalent. All three of these printer systems were destroyed in the fire of May 1977.

In rebuilding the TRADAT systems to the new configuration immediately after the fire, a new Anadex printer model DP-650A-21 was procured and modified to interface directly with the TRADAT system. Since the Anadex printer differed from the Hewlett Packard in physical configuration and electrical interface requirements, it was necessary to modify this printer in the same manner in which the prototype had been modified prior to the fire. The modified printer is shown in Figure 16. The modification was essentially simple in nature: the normal printed circuit connector used for input to the Anadex was simply rewired to an interface electronics card, which consisted of fifteen hex buffer chips (RCA model CD4050AE). Inclusion of these chips permitted the normal 10 volt drive signals for the HP5050B to be buffered and reduced to the 5 volt level required for operation of the Anadex printer. The power for operation of the inverter chips was taken from the internal 5 volt supply of the Anadex printer, and the card was mounted internal to the unit (Two of the buffer chips were provided as spares to provide for future modifications to the system with anticipated changes under the following contract.)

In order to permit use with the same interconnecting cables used between TRADAT and the HP-5050B, connectors identical to the 5050B input connectors were installed on the rear of the Anadex printer. Input connections from these Hewlett Packard type connectors were then taken to the buffers in such a way as to accomplish the required conversion from the 18 hammer configuration (numbered left to right) on the Hewlett Packard equipment, to the 21 character drum (numbered right to left) in the Anadex printer. With this conversion, the Anadex printer was rendered completely compatible with the TRADAT output system capability and the Hewlett Packard input cables.

An additional Hewlett Packard 5050B printer was also purchased in rebuilding equipment after the fire and is presently being used with the TRADAT IV system; interfacing is according to the original design. Since the Anadex has been converted for compatability, either printer may be used with either Tradat system.

6.6.2 For convenience in setting the optical/electrical axes for boresight configuration when tracking with any of the autotrack antennas, and also an aid to evaluation of the system, small low powered S-band sondes were designed under earlier contract number F19628-72-C-0139. The design of these

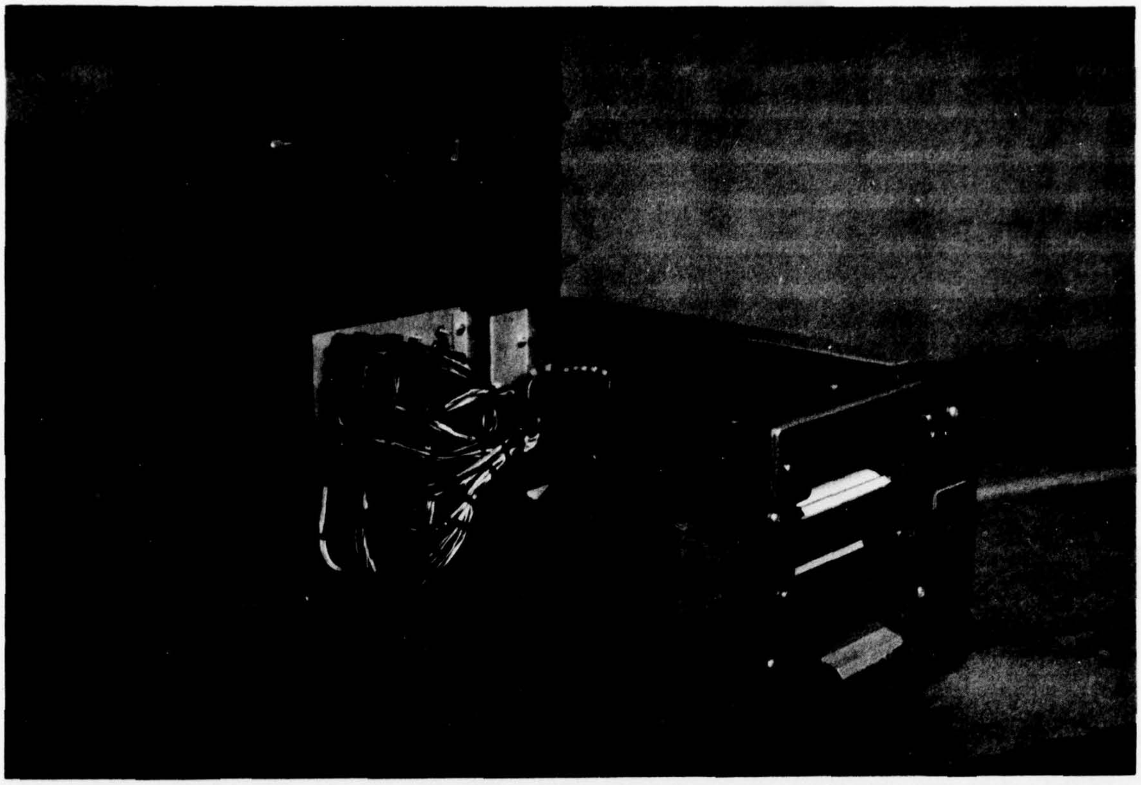


Figure 16. Anadex Printer, Modified for TRADAT

units was reported in detail in Scientific Report No. 3 to this contract (Reference 8). Each sonde is tunable to selected frequencies within the region of 2200 to 2300 MHz, and provides approximately 50 milliwatts of unmodulated RF power. (Power output is adjustable.) Units are equipped with an automatic cutoff circuit to kill the associated battery after approximately two hours operation to free the spectrum and eliminate possible shift in frequency as the battery is discharged. Easily available transistor radio batteries (9 volts, type 2U6) are used as the prime power source, down-regulated to an operating potential of 12 volts to stabilize transmitter frequency. A simple voltage-sensing shunt load circuit is incorporated to sense when the battery decays to the point where regulator operation is inadequate, whereupon a 68 ohm load is immediately switched across the battery to quickly drop the voltage below operating potential and turn the unit off. Radiation is by means of a short stub antenna, attached directly to the oscillator tank circuit. A complete sonde transmitter weighs approximately 55 grams, and approximately 75 grams more is required for the associated batteries. The entire system is

encapsulated in foam to provide thermal insulation for a lightweight and ingestible package which can be suspended from balloons without hazard to aircraft. Approximately 20 such units have been built to OSU drawing C36MA07, or later revisions in mechanical configuration, and used in support of this contract. The sonde is normally launched on a meteorological balloon, inflated with helium to a diameter of approximately 3 feet. The system has proven very reliable and has been an asset to calibration when used to accomplish alignment between the electrical boresight axis and the optical siting telescope on each tracking antenna. A balloon is launched and the tracker system put in the automatic tracking mode. The telescope is then colliminated by visual observation until the cross hairs are centered on the balloon at a reasonable distance, so that parallax correction between the sonde and the supporting balloon can be considered negligible. The sonde permits the evaluation of the autotrack performance of the system against low-powered sources at reasonable ranges and also assists in calibration and set-up for each mission; such sondes are customarily launched to test the system after shipment and installation at a launch site, and to verify the proper alignment prior to conducting an operational mission.

6.6.3 As a developmental project in connection with the tracking and trajectory work under this contract, it was recognized that future applications would require a more sophisticated approach to the processing of the raw trajectory data than was afforded by the early versions of the TRADAT system. As a result, a decision was made to explore the use of microprocessor elements as online data processing peripherals to the TRADAT system. As a starting point for this development work, a simple (KIM-I) microprocessor unit was procured and familiarity established through some simple bench operations. In order to test the feasibility of the planned development, an obvious first application was use of the KIM-I to operate on the normal TRADAT output data (the serial pulse train used for PCM data recording) and convert it into a more useful and flexible presentation, both in real time and in playback of tape data. Investigation of the capability of this device indicated that storage and latch logic internal to the KIM-I system was inadequate for the desired operation, and so breadboard hardware was developed to add two kilobits of extra random access memory (RAM), together with appropriate logic, in order to expand the capability and interface the computation power of the KIM-I to the digital printers normally used with the system. The first application was developed

for testing in connection with the BAMM launch support; the experimental system was set up in such a manner as to permit the serial data coming in from the ranging system to be processed from its normal slant range, elevation, and Azimuth vs. time form into output data which would include the true altitude and North-South/East-West location of the item being tracked, as a function of time. Limitations in calculating speed indicated that this could reasonably be accomplished with a 1 per second update. Since dedicated memory was not available within the KIM-I and the program loading was rather lengthy in nature, a program was developed and stored on a magnetic tape cassette; the program was loaded from cassette into the KIM-I after power up for each operation. This proved a slight disadvantage, as the time required for programming after a power outage was substantial because of the low speed with which the system could be reprogrammed for operation. It proved feasible to use this to demonstrate the power of the system, and it was accepted as a temporary expedient in testing the concept. It will be replaced with dedicated PROM elements in future versions of this equipment, to provide a specialized memory and program capability which are available at turn-on.

The basic system developed used the serial data stream from TRADAT and, through a subroutine, decoded the PCM wave train coming in to the desired data words, converted each to binary form, then addressed and stored these for use in the main routine. Data was extracted from the 1 kilobit data stream, coming in at a rate of 10 frames per second, only on each even numbered second by recognizing the .0 code in the serial time data portion of the input stream.

As soon as this data was stored, the KIM-I began to process through the main routine to provide the desired data. The main routine utilized both internal subroutines in the KIM-I and extra subroutines stored in the outboard memory. All calculations were performed with 40-bit binary numbers, but converted for output to the printer to 6-digit binary-coded decimal form. Calculated values are placed in storage, then fed out to drive the printer when the calculation is completed. Speed was such that a full set of calculations could be accomplished in approximately 0.6 seconds, thus enabling the machine to print out each 1 second data sample before beginning the next set of calculations.

The subroutine recognizes the fact that an even second is present in the serial stream of input data. It immediately processes time in hours, minutes and seconds, the Elevation angle, the Azimuth angle, and the slant range. The

for testing in connection with the BAMM launch support; the experimental system was set up in such a manner as to permit the serial data coming in from the ranging system to be processed from its normal slant range, elevation, and Azimuth vs. time form into output data which would include the true altitude and North-South/East-West location of the item being tracked, as a function of time. Limitations in calculating speed indicated that this could reasonably be accomplished with a 1 per second update. Since dedicated memory was not available within the KIM-I and the program loading was rather lengthy in nature, a program was developed and stored on a magnetic tape cassette; the program was loaded from cassette into the KIM-I after power up for each operation. This proved a slight disadvantage, as the time required for programming after a power outage was substantial because of the low speed with which the system could be reprogrammed for operation. It proved feasible to use this to demonstrate the power of the system, and it was accepted as a temporary expedient in testing the concept. It will be replaced with dedicated PROM elements in future versions of this equipment, to provide a specialized memory and program capability which are available at turn-on.

The basic system developed used the serial data stream from TRADAT and, through a subroutine, decoded the PCM wave train coming in to the desired data words, converted each to binary form, then addressed and stored these for use in the main routine. Data was extracted from the 1 kilobit data stream, coming in at a rate of 10 frames per second, only on each even numbered second by recognizing the .0 code in the serial time data portion of the input stream.

As soon as this data was stored, the KIM-I began to process through the main routine to provide the desired data. The main routine utilized both internal subroutines in the KIM-I and extra subroutines stored in the outboard memory. All calculations were performed with 40-bit binary numbers, but converted for output to the printer to 6-digit binary-coded decimal form. Calculated values are placed in storage, then fed out to drive the printer when the calculation is completed. Speed was such that a full set of calculations could be accomplished in approximately 0.6 seconds, thus enabling the machine to print out each 1 second data sample before beginning the next set of calculations.

The subroutine recognizes the fact that an even second is present in the serial stream of input data. It immediately processes time in hours, minutes and seconds, the Elevation angle, the Azimuth angle, and the slant range. The

information (except for time) is abstracted from the data stream, inverted to 2's-complement and stored in the work space, together with any desired offset angle corrections. The microprocessor then shifts to the main routine. The main routine, through a series of external and internal subroutines, then goes through the following steps: the slant range and Elevation angle are converted to a ground range and altitude value, effectively converting two-dimensional polar coordinates to rectangular form. The altitude is then corrected for curvature of the earth, and the values for the corrected altitude and ground range stored. (Since curvature of the earth has little effect on the ground range but a significant effect on the altitude in this particular calculation, ground range was not corrected for curvature of the earth.)

The ground range and Azimuth angle are then used, through a similar polar-to-rectangular coordinate conversion, to derive values of North-South displacement and East-West displacement with respect to the tracker. At the end of this step, the system has in storage the North-South, East-West, and altitude components of trajectory, together with time. The altitude has been corrected for curvature of the earth.

The KIM-I then checks to see if the calculation should be offset from the tracker site to the launch site, or some other desired point. If so, the Cartesian coordinate data is translated to the desired location by a simple subtraction process, operating on the X, Y and Z components (represented by north, east, and altitude in the storage bank).

The result of these calculations is now converted back to 6-digit BCD form and placed in the storage register for eventual use in printing out the data.

As soon as all data is available and the printer is ready to accept data, the proper latches are provided as output signals to the print hammers of the associated printer, which prints out data in the form of the range time (in hours, minutes and seconds) the North-South East-West range components, the Azimuth angle, the Elevation angle, the slant range to the vehicle, the mode of tracker operation, any offset corrections which are being used, the true altitude, and the true range. The system then waits for the next even numbered second in the input data train and repeats the sequence.

Clocking is generated from the input data stream, to permit it to adjust automatically to variations between real time and tape playback. Print commands and inhibit signals are also generated internally.

The routine used generates only hard copy for each second of data, and has no storage capacity for data that is being processed at any given point in the subroutine.

This system was successfully used in the BAMM support mission, to provide digital printed data of the trajectory elements outlined above.

6.7 Tracking and Trajectory Support Work

Work during this contract period also involved the conversion of some trailers used for field support purposes. Conversion for support of the BAMM program involved both the Canoga antenna trailer (USAF registry number HNX00267) and a portion of the work done on the AFGL instrumentation van (USAF registration number 52X00211). A third trailer (USAF registry number 52X00213) was also sent to OSU for modification and use, initially as a mobile operating site in support of BAMM, then later use for general support purposes.

6.7.1 Modification and rework of the Canoga tracker system was described in section 6.4 of this report. This involved conversion both on the Canoga tracking antenna itself and in the associated control electronics; the control electronics were physically located within the 52X00211 instrumentation van. This work was actually done in two stages: an initial conversion prior to the first BAMM mission, and some additional modification and rework of the tracker system which was accomplished between the first and second BAMM mission.

6.7.2 The instrumentation van, S/N 52X0211, required a number of changes in updating and preparing it for the new usage. This van had been originally instrumented at AFGL some years ago, and a general update was desired in connection with the special usage for the BAMM program. The changes made were described in detail in the log book and modification data supplied with the instrumentation van when redelivered to AFGL. A detailed discussion of the exact nature of all the changes made is beyond scope of this report, but the changes may be summarized as involving a number of types of work which were done in preparing it for anticipated usage.

As delivered, the trailer had been wired for a 3 wire Delta distribution system, and the loads balanced for the equipment originally installed in support of earlier series of missions at the Ft. Churchill Research Range, Canada. For compatibility with proposed use, the whole AC power distribution system was changed. Conversion was made to a 3-phase, 4-wire balanced Wye distribution system, with 115 volts from each leg to the common neutral (208 volts

between legs). While accomplishing this changeover in distribution, it was also necessary to rebalance loads for the proposed new installation and proper division of power to the racks. Additional AC power distribution was added internal to the instrumentation racks in the trailer, and also along some benches which were installed in the course of the revision. The electrical heating system also required rewiring for the new distribution system, and was so arranged as to have both a "low heat" mode and a "high heat" mode for Artic operations. To conserve energy, the "low heat" mode normally operates only a portion of the heating capability.

The trailer had originally been equipped with a central air conditioning system, ducted through the ceiling and into all cabinets. The original ducted heat exhaust system was completely removed from the trailer, and the blowers which had been provided to circulate outside air through the equipment racks were removed. Blower cabinets were also removed, permitting space for additional equipment installation. Removing the internal duct work from the equipment racks resulted in a considerable expansion of the volume capability of these racks; equipment cooling was provided by substituting "muffin" type fans at appropriate locations so as to take the cooled air within the trailer, circulate it through the equipment racks, and exhaust against the walls (rather than to the external air). This increased the heat load on the air conditioner, but simplified enormously the air distribution system.

Many of the items previously installed were no longer required, and all equipment was removed from the racks. Two racks were added to the trailer, to provide space for additional equipment. The equipment allocation within the racks was changed considerably to provide more convenient location and centralization of equipment. The aft end of the van was converted into an operator's console, with centralized communications capability above in a group of three equipment racks, supplemented by storage cabinets for spare modules. This installation included rack #8, which contained the IRIG time code generator, the RF distribution amplifier, and portions of the RF receiving equipment. Rack #9 was used as a centralized location for S-band and P-band telemetry receivers. Rack #10 was allocated for communication equipment. Space below the console also contained some timing distribution amplifiers and audio equipment for voice communications.

The right hand side of the trailer (as viewed looking toward the operator's console) was assigned for analog telemetry equipment in rack numbers 1,

2, and 3. Rack #1 contained a clock and loud speaker for the voice net, the telemetry calibrator, a Honeywell 14-channel galvanometer strip chart recorder, Panoramic indicator, and a special voice/multiplex (described in section 7.8).

Rack #2 was assigned for FM/FM analog discriminators, together with the main distribution patchboards for the trailer. A total of 21 GFD-13 discriminators were installed in this rack, together with the fan cooling system and a series of 7 patchboards for interconnection of various items within the station. The central patchboard location connected to all equipment throughout the trailer with the exception of a special RF patch panel, near the antenna entry and receiver rack. The bottom of this rack also contained a 4-channel AGC amplifier. Rack #3 contained a Sanborn model 7700 8-channel oscillograph recorder with associated controls. Auxiliary equipment included an EMR-4140 tunable discriminator, a Honeywell T6GA-500 6-channel galvanometer amplifier, and a 2-channel Video amplifier for distribution purposes. Immediately to the right of these three racks was a workbench top, on which was installed a Sabre III magnetic tape recorder, and wall cabinets were located above the bench for storage of parts and manuals.

The opposite side of the trailer (on the left, approaching the operator's position) was assigned for four equipment racks and a small work bench, on which was mounted a second Sabre III recorder. (This work bench was converted from the previous blower installation, to provide a storage cabinet for miscellaneous equipment below the Sangamo Sabre III recorder.) Rack #4 was simply wired with normal distribution for AC power, a blower and power control system, and some blank BNC cables to the patchboard. This was reserved for installation of PCM equipment at some future date.

Rack #5 included a VuData model 1200A 7-channel monitor scope and a switching panel to permit use of this scope with any of the available tape recorder input or output signals. The remainder of this rack was reserved for installation of video tape recorders for the TV link on the BAMM mission and some other special purpose equipment. Again, a few spare cables were provided from this rack to the patchboard for future use.

Rack #6 was primarily devoted to an Ampex model FR-1600 magnetic tape recorder.

Rack #7 consisted of the tracker and trajectory data equipment, supplemented by general purpose test equipment which included a HP-5245L frequency

counter and a 2-channel monitor oscilloscope, Tektronix model R-564B. Immediately below this were the data processor and tracker antenna controls for the Canoga autotrack antenna. Immediately below the Canoga controls were located all the components required for the TRADAT system which was installed by OSU. This consisted of an ElDorado 1706 time code generator and reader, and a modified GR1191 time interval counter for ranging. The basic TRADAT range code generator and data coder/decoder chassis was immediately below this, and the lowest unit in the system was the TRADAT ranging transmitter, Model OSX430, from the original prototype ranging system. An 8 3/4 inch blank space was reserved within this cabinet for potential installation of the HP-5050B digital printer, but no installation was made during conversion.

The opposite end of the trailer was used as the main power control panel with monitor meters and controls for the heating, air conditioning, and DC power system, all of which were installed in the forward compartment. (This forward compartment was also used as storage for associated cables and miscellaneous equipment when the trailer was shipped.) A rack for the three helical antennas (used for TRADAT and for potential command) was also installed, in order to permit stowing three of the OSU model D35ET01 antennas while the trailer was being moved.

In order to accomplish the desired revision, it was necessary to dismantle the trailer completely, remove the duct work, then completely rewire the trailer and reinstall all equipment in the desired configuration. A major portion of this effort was involved in rewiring the entire patchboard complex, which included seven patchboards, each containing 52 standard ADC patch connectors. Patchboards not only accommodated all equipment installed at OSU, but also a number of spare cables, blanks and parallel positions for convenience in operating.

Coaxial wiring was installed for input and output connections from all three tape recorders to the patchboard and to the 7-channel monitor scope.

Both the PAM decommutator and the voice/multiplex box described in sections 7.3 and 7.4 were constructed specifically for installation in this trailer.

6.7.3 A third trailer which had previously been equipped for support of the falling sphere program was delivered to OSU for use as a mobile support site. This trailer included very little equipment when received, since most of the sphere support equipment had previously been removed, and the system

was intended only as a general purpose temporary movable building, in which equipment could be installed as the need arose. Trailer number 52X00213 was accordingly stripped of all remaining equipment for refurbish. A set of changes were made to make it of better utility.

Two banks of three racks each were installed; one on the left rear and the other near the right front. Each such rack was equipped with AC power distribution from the master power input panel, which was located on the left wall. Since the system would be used from a mobile generator power with uncertain regulation capabilities, AC voltage regulators were installed in five of the six racks in order to permit better control of the AC power where the electronic equipment was to be operated. AC wiring was also added along the walls and the work bench area to make this area more usable, and lighting was added in the form of flourescent light fixtures on the ceiling.

Two window air conditioners were purchased and installed, one forward and one at the rear of the van, to provide cooling for operation in hot environments.

A U-shaped bench was constructed at the front of the trailer as a work table, with storage space located below. A second work bench was installed at the right rear of the trailer, running along the side wall, for a similar purpose, with storage space below.

A large storage compartment, located beneath the floor of the trailer and accessible from outside, was refurbished and placed in useful condition for equipment and supply storage while in transit.

A cable pass-through panel was installed in the right side wall for interconnection of the trailer with other equipment, when used in the field.

First usage of this trailer was in support of the BAMM mission. All of the racks are normally regarded as simple general utility racks provided with shelves, as well as normal rack rails for rack-mounted components. Intercabling is provided by standard coaxial cables from unit to unit, without use of patch panels. The equipment installed will vary with the support mission. For the first BAMM support mission, the trailer was used as an auxiliary tape recording site and contained some receiving equipment as well. In addition, the forward U-shaped area was assigned for use of the command system as an operator's console in connection with the BAMM mission. All of this equipment was removed immediately after completion of the mission.

The trailer has been returned to OSU and is currently awaiting reassignment.

7.0 OTHER GROUND SUPPORT EQUIPMENT

As required by 0001AB, subparagraphs (a) and (b), maintenance, operation, and improvements to existing GSE for special requirements has led to the development of many items. Some of these were based upon earlier designs and others were developed specifically for employment during the work under this contract. Equipment constructed under this portion of the contract was not from an organized development program, but essentially met needs imposed by various support missions which occurred in the course of the contract. As such, many of the items are unrelated; they were provided when a requirement arose for specific satisfaction of some unique problem noticed in connection with the launch of a payload vehicle. However, the equipment so developed has sometimes proven of general utility and is lumped together for description within this section.

7.1 Gyro Decoder

Under preceding contract F19628-72-C-0139, a special purpose COS/MOS gyro PCM decoder was developed for use with the Space Vector gyro systems. These are supplied for position references on many AFGL payloads. (This unit was described in detail in section 4.3.4 of Reference 6.) In brief, the unit was built to decode eight basic gyro formats at selected bit rates, from several different versions of the Space Vector platform equipment. Both 8-bit and 10-bit versions of the digital gyro output are accommodated; the decoder is capable of decoding either pitch and yaw data from the three-word format, or all three axes of pitch, roll and yaw from the four-word formats normally involved. Both digital light displays (of the full digital data) and analog converter panel meter displays are provided, together with galvanometer driver outputs from the analog signal for display on strip charts as permanent recordings. Normal display is for pitch, yaw, and roll data; the number 3 display may also be switched to the synchronizing word, if desired. A fuller description of the unit is offered in Reference 6. A second unit identical to that constructed under the previous contract was built and delivered to AFGL for support of payloads utilizing the gyro system, as a portion of the ground support work under this program. No modifications were incorporated in this

second model, designated as OSU model D36GT02.

7.2 Sphere Decoder

Because of the great convenience offered in field operation by the gyro decoder described above and the schedule of a large number of launch support missions for falling sphere experiments, it was decided that development of a special decoder (similar to the gyro decoder) for a single type of PCM telemetry link would be advantageous, both for checkout of the instrument and for ground support of missions in which this instrument is flown. (Previous support of falling sphere missions had required the commitment of several PCM decoders in order to check out the instrument operation with adequate confidence prior to flight. Two 5-channel decoders and a single channel decoder have been committed to this mission in the past.) Since many of the sphere programs are conducted at the remote launch site at Kwajalein Missile Range, logistic factors frequently caused unavailability of general purpose decoding equipment for long periods of time. A special decoder was accordingly developed, as shown in OSU drawing C90FS01.

7.2.1 The final decoder included a self-contained power supply for operation from standard 115 volt AC power. It was constructed within a case with dimensions of 7.5 centimeters high by 38 centimeters wide by 23 centimeters deep. Total weight was only 4.2 kilograms, and power consumption is approximately 50 watts. The decoder is relatively inflexible for other uses, since it was specifically developed for compatibility with the PCM signal from the sphere instrument. The input signal is Biphase-Level code at a bit rate of approximately 13 kilobits per second. The frame length consists of 16 words, 8-bits in length, including a Barker code sync word followed by 15 data words. All 15 data words are automatically decoded by the unit and provided in the form of analog output signals (with suitable galvanometer driving amplifiers) on the rear panel for display on a stripchart recorder. A 16th decoder provides both digital light monitors and analog panel meter monitor, as well as an auxiliary galvanometer drive on the rear panel. The switchable channel can be used to select any data word (or the sync word) for display purposes. The decoder makes use of the self-clocking capability of the bi-phase format to simplify the ground system. Circuit parameters permit automatic lock-in of ground equipment for bit rates between 9.8 and 16.5 kilobits, with no adjustment provided. Frame synchronization is preprogrammed to the desired

sync word, and the blanking and reset systems are hard-wired for compatability with the incoming signal. A "sync loss" light is provided on the panel to indicate if data is lost or signal quality is poor. The system requires a single coaxial connector to the associated video feed from the receiving station, and operation is completely automatic over ranges of video signal from 0.25 to 20 volts peak to peak level. Signal-to-noise ratios of 3:1 for the receiver are adequate for satisfactory operation. For a normal sphere payload, threshold sensitivity for this decoder is approximately -110 dbm when used with the DEI TR-711 receiver at the normal bandwidths and video filtering. A polarity switch for either normal or inverted sense to the video input is provided as a convenience; internal calibration also is provided for signals of 0%, 50% and 100% of full scale range for the PCM system. The output current capability for each word output is approximately 10 milliamperes full scale, which is adequate for normal 1000 Hz galvanometers used in the associated recording instrument. This system was built with wirewrap technique on a single circuit board; a total of 176 inline chips were used, with DIP sockets to facilitate component replacement and service in the field. A 16-pin inline block, compatible with the standard DIP socket, is also used for elements for the clock multivibrators, to permit future changes in the event later models of the sphere system operate on a different frequency.

7.2.2 Operation of the system is best understood by reference to Figure 17, OSU drawing B90FS02. Input video data in the form of the PCM wavetrain is first processed in IC101 to condition the data for use elsewhere in the equipment. One section is used as the data inverter to permit use of the positive or negative sense polarity (depending upon the drive point) to the decoder. A portion of the data conditioner is also used as a data loss detector, fed through an OR gate and blanking flip-flop to a panel indicator which will indicate loss of synchronization in the event the system fails to lock on, or if data quality is poor. One additional section of the data conditioner serves as a trigger generator to provide clock pulses to the remainder of the system.

IC102B serves as a bit clock multivibrator, generating both positive and negative sense clock signals. The positive clock signals are fed through IC103, an 8-bit counter which counts down to word rate. The output word clock is then counted down by word counter IC106 to generate the proper frame length signal and also to provide address lines to the associated word decoder.

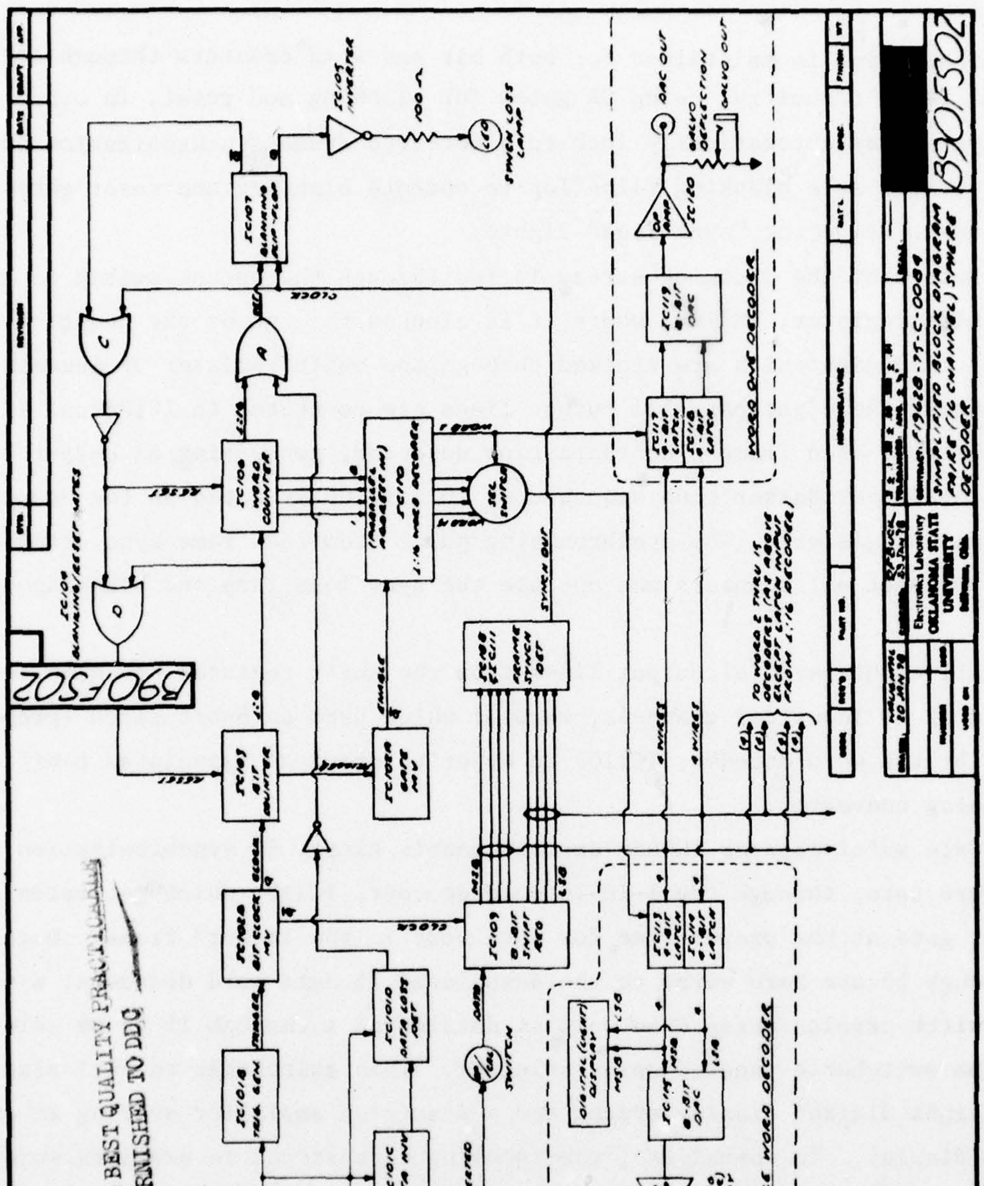


Figure 17. Sphere PCM Decoder

Synchronization is maintained for both bit and word counters through conventional reset circuitry, using OR gates for blanking and reset, in order that the system may automatically lock to a detected frame synchronization word. IC107 serves as a blanking flip-flop to operate blanking and reset gates, as well as to drive the "sync loss" light.

Data from the incoming stream is fed through the op-cal switch to an 8-bit shift register, IC 109, where it is clocked through by the negative sense clock. All eight bits are clocked through the shift register at incoming data frequency; the eight parallel output lines are connected to IC108 and IC111, which serves as a frame synchronization detector, generating an output signal when the proper Barker code sequence of 101 110 00 is noted as the contents of the shift register. (The synchronizing pulse from the frame sync detector is used to reset all counters and operate the sync loss lamp and blanking flip-flop.)

All eight parallel output lines from the shift register are also fed to a series of 16 identical channels, each of which uses an 8-bit latch (properly gated by the word decoder, IC110) in order to drive an associated 8-bit digital-to-analog converter.

Gate multivibrator IC102A derives enable gates, in synchronization with the word rate, through the 1-in-16 word decoder, IC110, which generates an output gate at the proper time for each word in the 16-word frame. Data words 1 through 15 are hard wired to the associated 15 data word decoders; a selector switch permits words 0 as well as data words 1 through 15 to be selected for the switchable panel display selector. This switchable channel also drives an 8-light digital display system and a precision amplifier driving an analog meter display. In normal use, the incoming data stream is examined word by word through the selector switch to verify incoming data (with either digital of analog monitors). The 15 data words are fed as separate signals to an associated strip chart recorder to permit automatic data recording during flight.

7.3 Single Channel PAM Decommutator (BAMM Support)

In connection with the fitting out of the AFGL support van for use in the BAMM program (described previously in section 6.7 to this report), one of the units supplied under this contract was a PAM decommutator. This system was designed to permit selection of any data segment from IRIG standard PAM

commutated data trains. The basic CMOS logic digital synchronizing circuits used in this decommutator were the subject of previous support and were developed under F19628-72-C-0139 for AFGL (Reference 9). The final unit which resulted and was incorporated within the van was an updated and repackaged version of a unit originally designed at AFGL by Capt. T. M. Lamb/LCS, and was described in an AFGL paper (Reference 10). The system was designed to operate for frame rates of 2.5, 5, 10, or 30 per second, with frame lengths of either 30 or 60 segments. Both NRZ (100% duty cycle) and RZ (50% duty cycle) formats were accepted by the unit. Input signal could come from either the raw commutated data wave train (0 to +5 volt dc span) or from positive or negative sense FM/FM discriminator output signals. Galvanometer current drive outputs were provided both for the raw commutator signal and for any selected decommutated channel. Current drive was adjustable from 0 to 25 ma on both of the selected output signals. The selected channel was also used to drive a digital panel meter as a monitor, and a pair of test jacks were provided for external monitor purposes. Auxiliary test point outputs were provided for channel sync, frame sync, and a clock monitor. Operation was entirely from 115 volt 60 Hz AC input power; internal supplies provided the $\pm$ 15 volt and +5 volt regulated outputs required for circuitry within the unit. In addition, a simple degenerative regulator operating from the +15 volt bus down-regulated to a +10 volt level for operation of the digital logic. The unit was constructed in very compact form, using a 1 3/4" high standard relay rack of 19" width and a depth of only 11" behind the panel. The completed model was designated as OSU drawing number D90PM01.

7.3.1 Clocking of the decommutator was provided by a phase-lock loop clock, operating at twice the sample rate of the incoming commutator data. The free-running clock frequency is compared with the input data by generating a signal at twice the normal sample rate; the doubling was done by using a one shot delay multivibrator to clock a D-type flip-flop, approximately one-half segment later than the incoming data stream. The incoming data stream was then combined with the delayed data stream through an exclusive OR gate to provide a double frequency output. Oscillator correction voltage was then obtained by comparing the phase of the clock and the incoming signal data. The error signal passed through a simple low pass filter to provide correction voltage for the clock chip.

7.3.2 Input data is conditioned by a series of operational amplifiers

for use within the unit. IC 102 serves as a simple voltage follower, providing the raw commutator signal drive to a galvanometer used as a monitor. The data conditioner channel takes the input signal through an adjustable gain control to set input level, then to IC101, an operational amplifier with a gain of 3:1. This output goes through a switching circuit, which permits selection of positive or negative sense discriminator output, or the raw 0 to +5 volt data stream as the input to the remainder of the decommutator. (A triple-pole switch introduces offset biases to accommodate either the positive or negative sense bipolar discriminator signals, or no offset bias.) The switch also connects the signal properly to IC103, an operational amplifier with a gain of approximately unity, which serves as the buffered amplifier driving the remainder of the circuitry. The data stream is shaped by Q101 and used to trigger IC108, which conditions the data in such a way to generate positive and negative versions of the wave train with very sharp leading edges; the two signals are slightly shaped and fed to an exclusive OR gate in order to detect transitions in data as clock pulses. These clock pulses are used to trip a one-shot multivibrator whose delay period is proportional to the sample rate of the incoming data stream. (This is used to achieve phaselock comparison with the internal clock oscillator, as described previously.) Data is clocked into shift register IC115 by clock pulses from the oscillator, and the four outputs of Q1 through Q4 are, after suitable inversion, fed to IC113 (a 4-input NAND gate) which serves as the frame synchronization detector by generating an output pulse when the shift register presents three segments of 5 volts, followed by segment of 2.5 volt level. The detected frame sync pulse is clocked into IC117, one output of which is used to drive a "lock" indicator light on the front panel, indicating system has established synchronization with the incoming data stream.

7.3.3 A sample aperture is developed in order to test the level of the input signal, then store and hold it, for decommutation. The sample aperture period duration is approximately one-quarter of the segment width and positioned near the center of the channel. This is automatically controlled by the speed selector switch and the time constants used in the clock and one-shot delay circuitry. Channel selection is accomplished by feeding the internal clock pulses into IC120 and IC121, a pair of 1-in-10 decade decoders. IC120 serves as a decoder for "units"; IC121 is the decoder for "tens." Selection of either 30 or 60 segment length per frame is accomplished by one

section of IC118 which combines either the 20 or 50 count with the zero reset of the units counter when selected by the front panel switch. A pair of associated digiswitches, S107 and S108, permit selection of "units" and "tens" identifying the channel which it is desired to decommutate. The selected channel number is combined in one section of IC119 and, after suitable signal conditioning, used as the channel synchronizing sample aperture to IC105, an FET switch which is so connected as to function as a conventional single-pole, double-throw switch.

Data from IC104 (the operational amplifier) is conditioned to the proper level by "gain" and "zero set" controls to present a true 0 to 5 volt data span at the output system. This data signal to IC105 is blanked except during the selected aperture, when it is gated through, stored in C104 and used as DC input voltage to the output amplifier system. IC107 serves as a voltage follower, driving the digital panel meter and external test jacks. The signal from this amplifier is also taken through a current driver IC106 and used as galvanometer drive signal for the selected output channel.

Only one unit of this configuration was constructed and this unit was installed in the AFGL instrumentation van while refitting it for the BAMM mission.

7.4 Multiplex/Voice Support Boxes

A frequent need has arisen in the course of this and preceding contracts for a convenient way to combine station housekeeping data into a form for recording on magnetic tape, together with the associated data being received from payload. Voice/multiplex boxes for this purpose have been constructed a number of times in the past. Each such box usually consists of a series of voltage-controlled oscillators to provide a multichannel FM analog signal (each VCO is modulated by one of the parameters which it is desired to record for housekeeping data). Earlier boxes provided only four or five channels for this function. A new support box (shown in Figure 18) was built during this contract to provide a total of eight available channels, together with the associated audio to combine voice data in the recorded train, and also to permit playback of the voice data from the magnetic tape records. In addition, since the parameters it is desired to monitor usually include signal strength indications from the associated receivers, a pair of AGC buffer-inverter units with DC offset capability were provided, to condition AGC signals for proper modulation of the associated oscillators in the multiplex stream. The voice

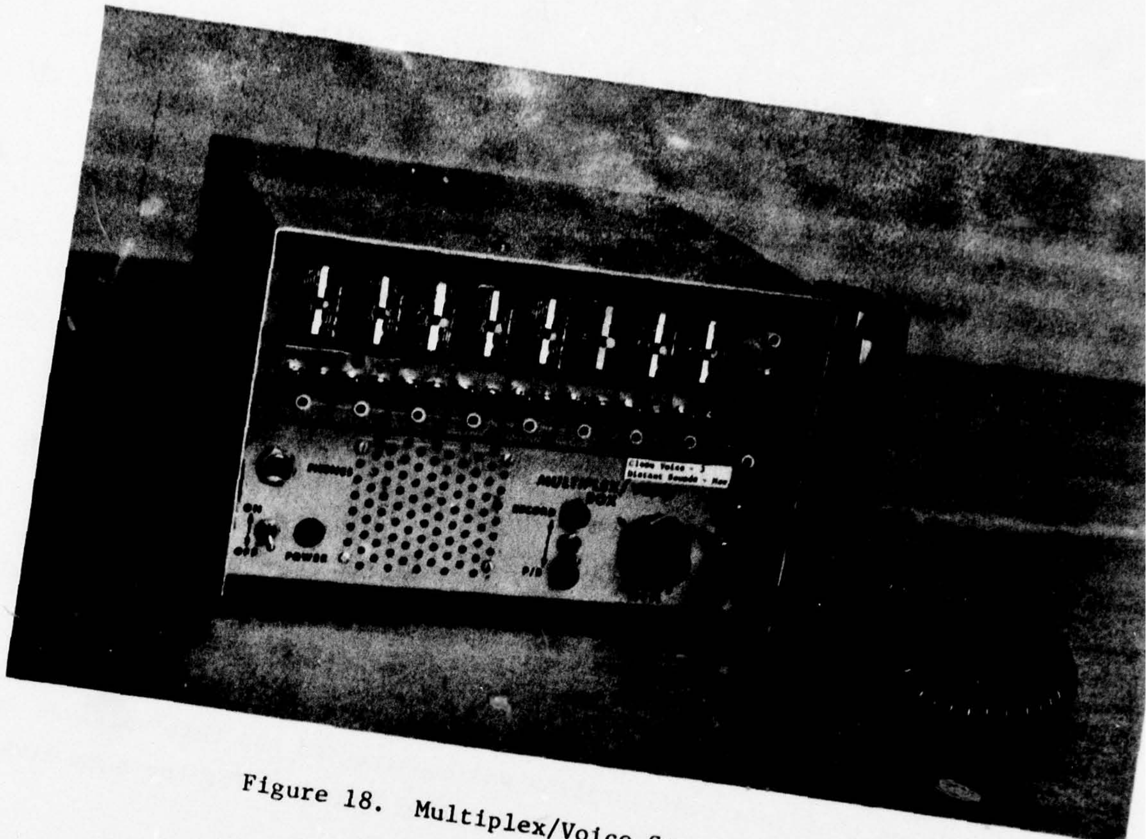
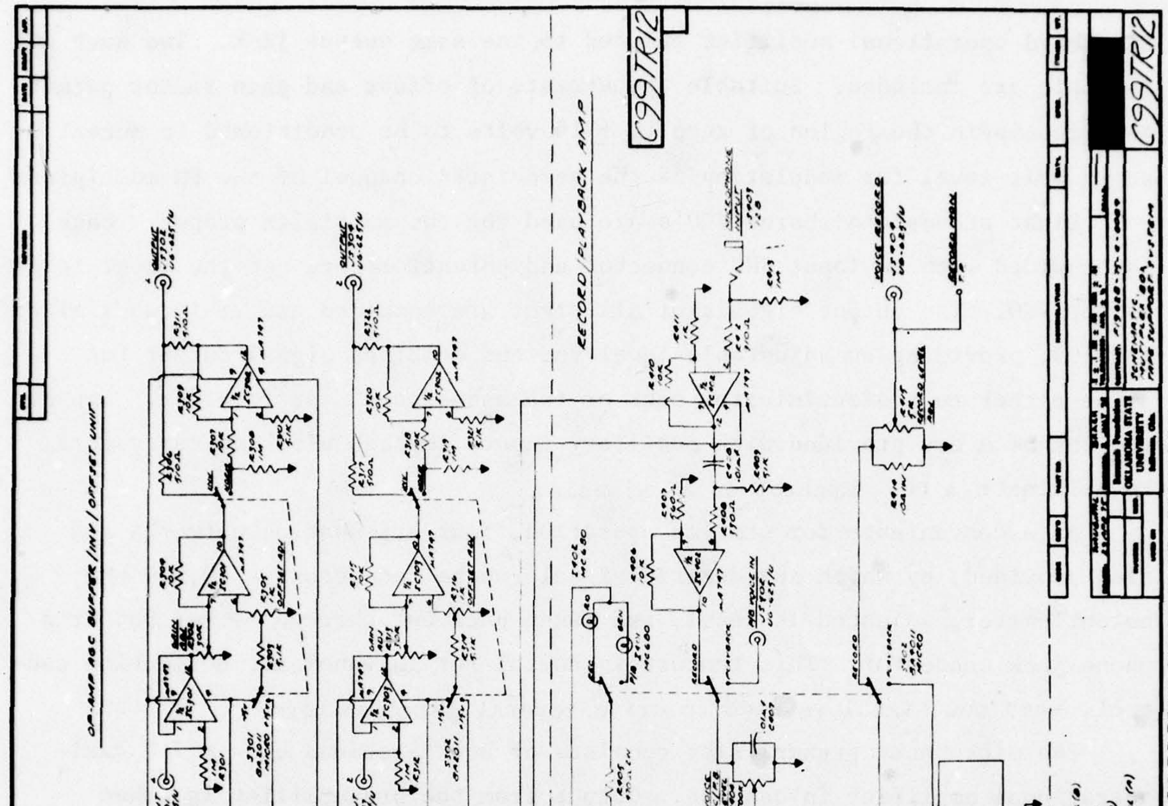


Figure 18. Multiplex/Voice Support Box

channel of this support box permitted operation from the microphone through a power amplifier to the output controls. Switching circuitry was included so that, in the "record" mode, the amplifier was fed to the record head of the tape recorder, whereas in the "playback" mode, the audio signal obtained from magnetic tapes was processed by the amplifier and used to drive the internal monitor speaker, or a pair of head phones. A power supply is provided for 110 volt 60 Hz power operation of the system. Figure 19 (OSU drawing C99TR12) shows the circuit.

The AGC amplifier circuitry is relatively straightforward. Three operational amplifiers are used in cascade for each such system; the input section serves as a buffering amplifier with an adjustable gain. Signal from this amplifier is then fed into a second operational amplifier, provided with an offset adjustment and switching arrangements to permit selection of either positive or negative polarity signals. When used in the inverted mode, output from this amplifier (after suitable offset) is taken directly to the output jack. If non-inverted operation is desired, the signal is inverted again by



THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Figure 19. Multiplex/Voice Box Circuit

the third operational amplifier and fed to the same output jack. Two such channels are included. Suitable adjustments of offset and gain factor permit AGC signals in the region of zero to $\pm$ 10 volts to be conditioned to normal 0 to +5 volt level for modulation of the associated channel of the FM multiplex.

Eight standard airborne VCO's are used for the multiplex proper. Each is provided with an input BNC connector and potentiometers set the input level to the VCO. The output signals of all eight are combined and resistance mixed in R109, providing an adjustable level for the combined signal output for drive either to a discriminator bank or the associated tape recorder. Two of the channels are provided with auxiliary inputs through blocking capacitors, to eliminate a DC component on AC signals.

As a convenience for station operation, four attenuation networks are also provided, by which any desired signal can be fed across a 10,000 ohm potentiometer, adjusted in level, and taken back out through either BNC or a phone jack connector. This feature is useful for galvanometer deflection control, when one signal is used to drive several galvanometers.

The microphone preamplifier consists of both sections of a μ 747 dual-operational amplifier in cascade. Output from the preamplifier is taken through the "record" switch across an adjustable gain control, through IC401 and to a MC1454G 1 watt audio power amplifier. Output from this amplifier may then be taken across a "record level" adjustment to the tape recorder, or (in the "playback" mode) through a transfer-switching headphone jack, to an internal speaker. To indicate the mode in which the voice system is used, a third section of the "record/playback" switch is also used to illuminate panel lights, indicating which mode the audio system is being used in.

Power supply voltages are generated internally by simple bridge rectifier circuits, and provide the $\pm$ 15 volts required for the operational amplifiers, as well as a +28 volt power bus for the associated VCO's and a down-regulated +14 volt supply for the audio amplifiers.

As mentioned in paragraph 6.7, a similar unit was constructed in slightly different configuration and installed in the AFGL instrumentation van for support of the BAMM mission. This unit was physically repackaged in order to duplicate the original multiplex unit which existed within the van. However, the additional features of the voice "record/playback" amplifier and a 100 KHz crystal reference oscillator were incorporated in this unit, designated as OSU model C99TR14. The final unit was built with a standard 19" relay rack panel

of 3.5" height and occupied a depth of approximately 10" within the trailer rack. All connections were brought to the rear of this unit for convenient connection to the patchboard in the AFGL van.

7.5 Four Channel Line Driver

As a result of the experience gained driving long coaxial lines in connection with the MSMP program, a four-channel high speed line driver, similar to that developed for incorporation in the MSMP coder, was provided as an auxiliary piece of ground support equipment. This is primarily for use in tests and development of the IRBS payload, which will have similar checkout problems. Circuit details are shown in Figure 20 (OSU A39AH01). Four independent line drivers were provided, each with BNC connectors for input and output. Each utilized the same Burr-Brown model 3329/03 hybrid integrated circuit power booster, described in section 5.4. Power for operation of all four channels was derived from a 110 volt 60 Hz power supply contained within the same box; a small module resulted which provided four independent drivers, each using 100 ohm isolation resistors to protect the amplifier against short-circuited 50 ohm coaxial cable loads. Each is capable of driving a 1000 foot long RG-8 coaxial cable. When suitably terminated, they will provide an output signal of approximately 3.5 volts from the standard 10 volt logic level normally used as inputs.

7.6 Five-Channel PCM Decoder Modification

In previous AFGL contracts, a number of general purpose 5-channel PCM decoders for ground support equipment have been provided. The original design of the OSU Model D90RP01 unit was described in detail in the final report to F19628-70-C-0147, under which this development was conducted (Reference 4). Two units of a slightly different design were later constructed under contract F19628-72-C-0172. These units were specially developed for use with the infrared payloads flown under that contract, and a description was offered in the final report to the contract (Reference 6). These units were quite flexible and, as originally designed, provided adequate capability for payload checkout.

In connection with the development of the high-speed equipment for the BAMM mission and the growing complexity in PCM formats, for MSMP and BAMM, it was recognized that these units needed updating for greater flexibility and use. The general control features originally designed into these systems

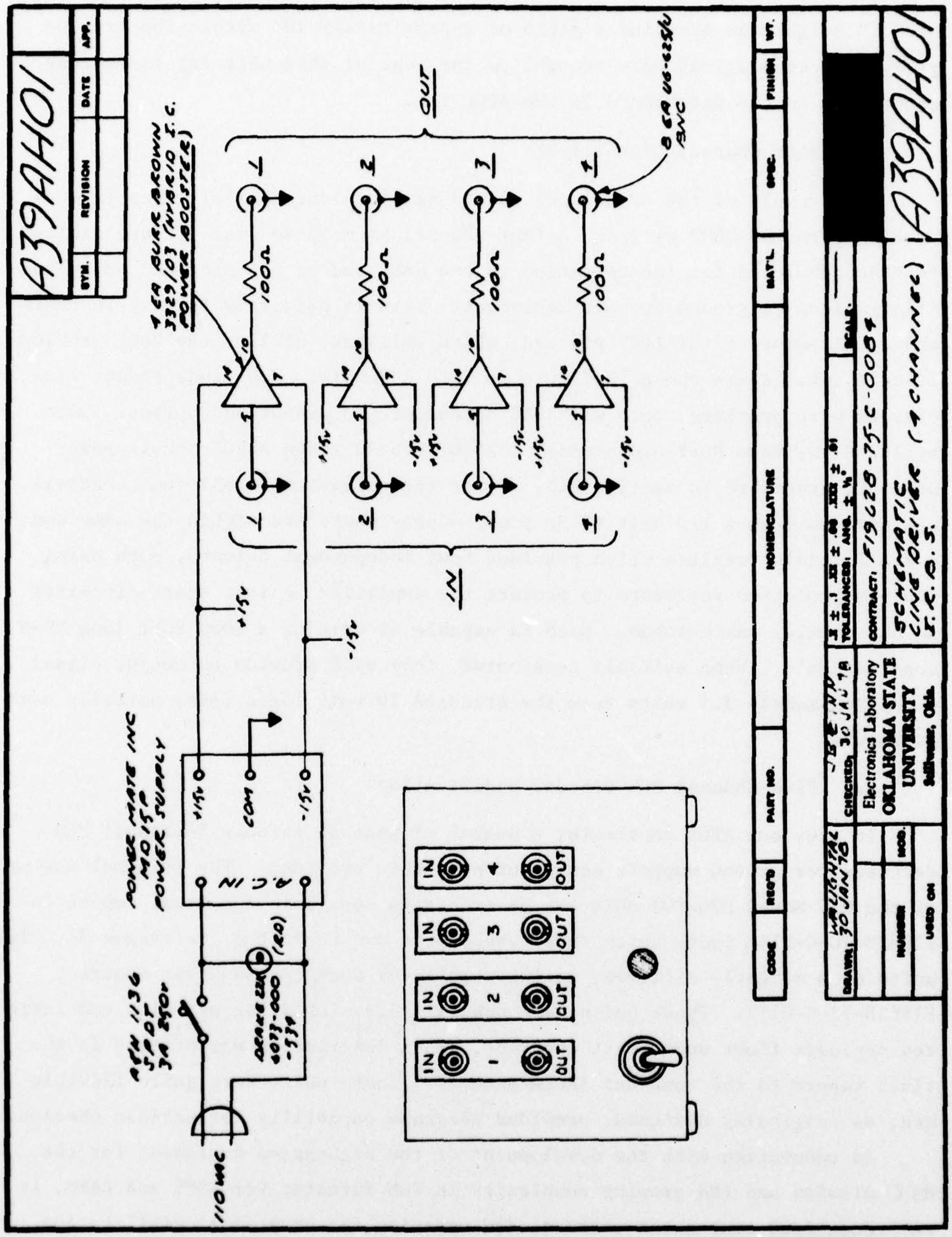


Figure 20. Four-Channel Line Driver

were retained, but some changes were made to improve flexibility.

The first change was made to raise the acceptable bit rate from the original design of 1.2 megabits per second to an upper limit of 1.8 megabits per second. This revision required some changes in the internal phaselock clock circuits of all four units, in order to raise the oscillator frequency. In addition, it proved necessary to modify the synchronizing circuits slightly to provide more reliable operation at the upper end of the bit rate range desired. Synchronizing circuits were modified by gating half bit-width high frequency clock pulses together with the normal synchronizing pulses of the original design, to provide narrow high-speed synchronizing signals for frame sync and channel selection. The changes were made by minor modification of the plug-in cards which were used in construction of the original unit.

An additional change was indicated to permit use of these decoders with more complex formats, in which there might be more than one subcommutated data frame and also in which the subcommutated data stream might require multiple presentations in a "super-subcomm" format. In order to extend the usefulness of these units, the approach adopted was one of designing an auxiliary unit and providing an electrical interface by installing a connector on the rear panel of each 5-channel decoder. These connectors were so wired as to provide operating power at a level of +5 volts and a reference ground to the outboard unit, which would be slaved to the 5-channel system. In addition, required timing signals were the word clock, the frame synchronizing pulse, and the subframe synchronizing signal. These were brought to this connector, as were the input signals to the number 1 and number 2 latch system of the 5-channel unit. This revision was made to permit their use with an auxiliary subcommutator selector unit.

7.7 Subcommutator Selector

As an adjunct to use of the 5-channel decoders with complex PCM formats in which there might be more than one subcommutated frame of data (or in which the subcommutated data frame appeared in a position remotely separated from the subframe I.D. word), and also for use in multiple samples of subframes which used the "super-subcomm" format, a special unit was developed under this contract. It was built as an accessory box, which could be attached to any existing 5-channel PCM decoder by a simple captive interconnecting cable. The subcommutator selector was designated as OSU Model C39MD01. The system

was constructed in a small box which can be placed atop the 5-channel decoder with which it is used; dimensions are 8.2 centimeters high by 18 centimeters wide by 10 centimeters deep. All operating power is provided from the main unit, as well as all the necessary synchronizing signals, and a small captive cable permits its attachment to a mating connector on the rear of the decommutator, as described in the preceding paragraph. A view of such a unit, attached to the main decoder, is shown in Figure 21. Two decade digital switches on the front panel permit selection of the word address of the subcommutated word, and frame, within the subcommutator format which is to be decommutated. In the case of super-subcomm formats, the number of words which space repeated words in the supercomm format are selected with the address switch. Selection of the mode of operation was made by a switch which permits either the single subframe selection or the supercomm spacing mode of operation; a second switch permits the unit to be disabled, or to display the selected decommutated data on either the number 1 or 2 latch and display system of the associated 5-channel decoder. Use of the number 1 latch permits digital light display of the data; use of the number 2 latch is restricted to analog meter display. In either case, the galvanometer drive from the associated digital-to-analog converter within the 5-channel decommutator permits data to be recorded on strip charts.

7.7.1 All synchronization and clocking signals for the unit are generated in the associated 5-channel decoder. The frame synchronizing pulse selected by this decoder is fed into the unit, together with a selected subframe synchronizing pulse and a word clock output. The associated 5-channel decoder must be properly set up to achieve both frame and subframe synchronization for proper operation of the subcommutator selector. The reference for subframe synchronization is the subframe sync word selected by the 5-channel unit. Since, in normal operation, the subframe sync word is actually subframe ID, the reference for operation of subframe selector will be with reference to the number of words beyond the selected subframe synchronization signal. If the ID word is selected as subframe sync, consecutive numbering of the selected subframe is accomplished with the subframe sync selector dialed for all zeros. Then, as the subframe ID word advances, the main frame synchronizing pulses will be counted as successive words within the subframe. The unit can be used to drive latch pulses into either number 1 or 2 latch and display systems of the associated 5-channel decoder. Since these units were also driven by

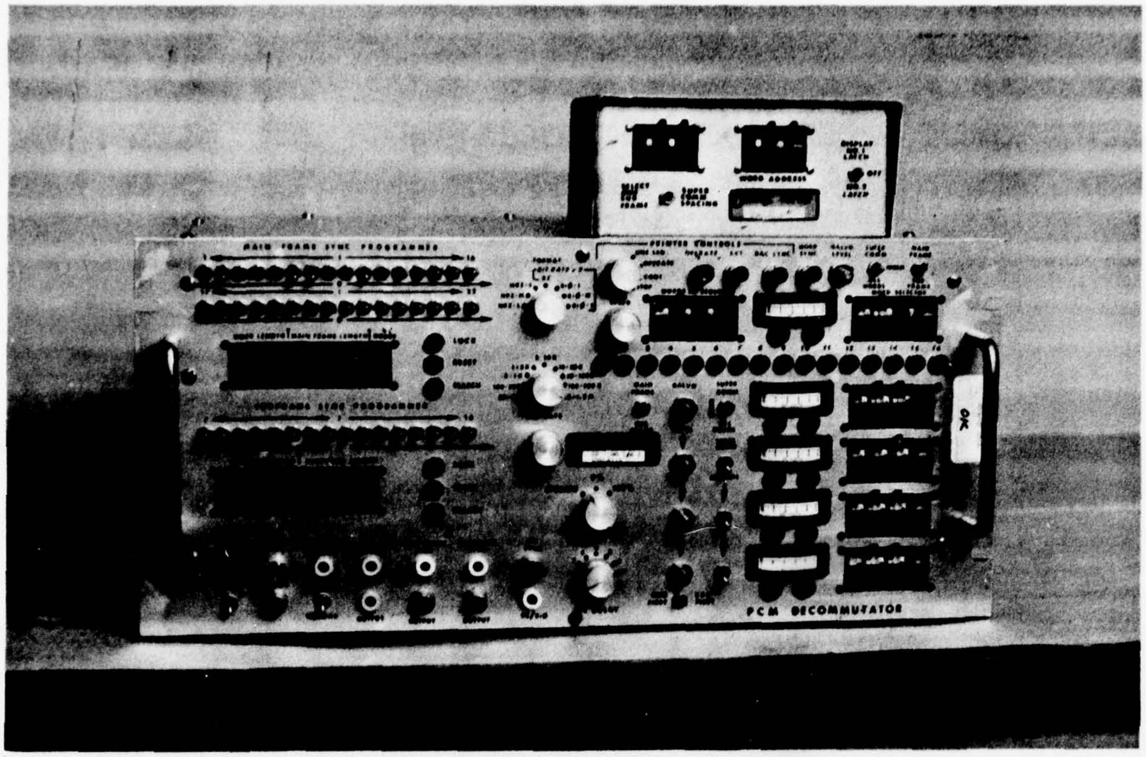


Figure 21. Subcommutator Selector
(above Five Channel PCM Decoder)

synchronizing circuits internal to the 5-channel decommutator, it is necessary to set the panel switch for the latch desired on the 5-channel decoder to some number beyond the subframe length to avoid inadvertent desynchronization by a sync pulse generated internal to the 5-channel decoder. A diagram of the circuit is shown in Figure 22.

7.7.2 In the normal subcommutator mode of operation, the selected subframe synchronizing pulse is fed through IC109 to generate a "clear" pulse, establishing a zero condition in the 2 decade counter formed by IC101 and IC102 in series. After reset by the selected subframe sync, consecutive frame synchronizing pulses are counted on the negative transition from the 5-channel decoder as clocking pulses into the subframe selector. IC101 provides 1, 2, 4, 8 BCD outputs to IC103, a 1-in-10 decoder chip. The output of IC101, which serves as a "units" counter, is used to advance IC102, which performs the same function for the second digit ("tens") and so permits the selection of subframes up to 99 in length. Parallel address lines from each of these decade

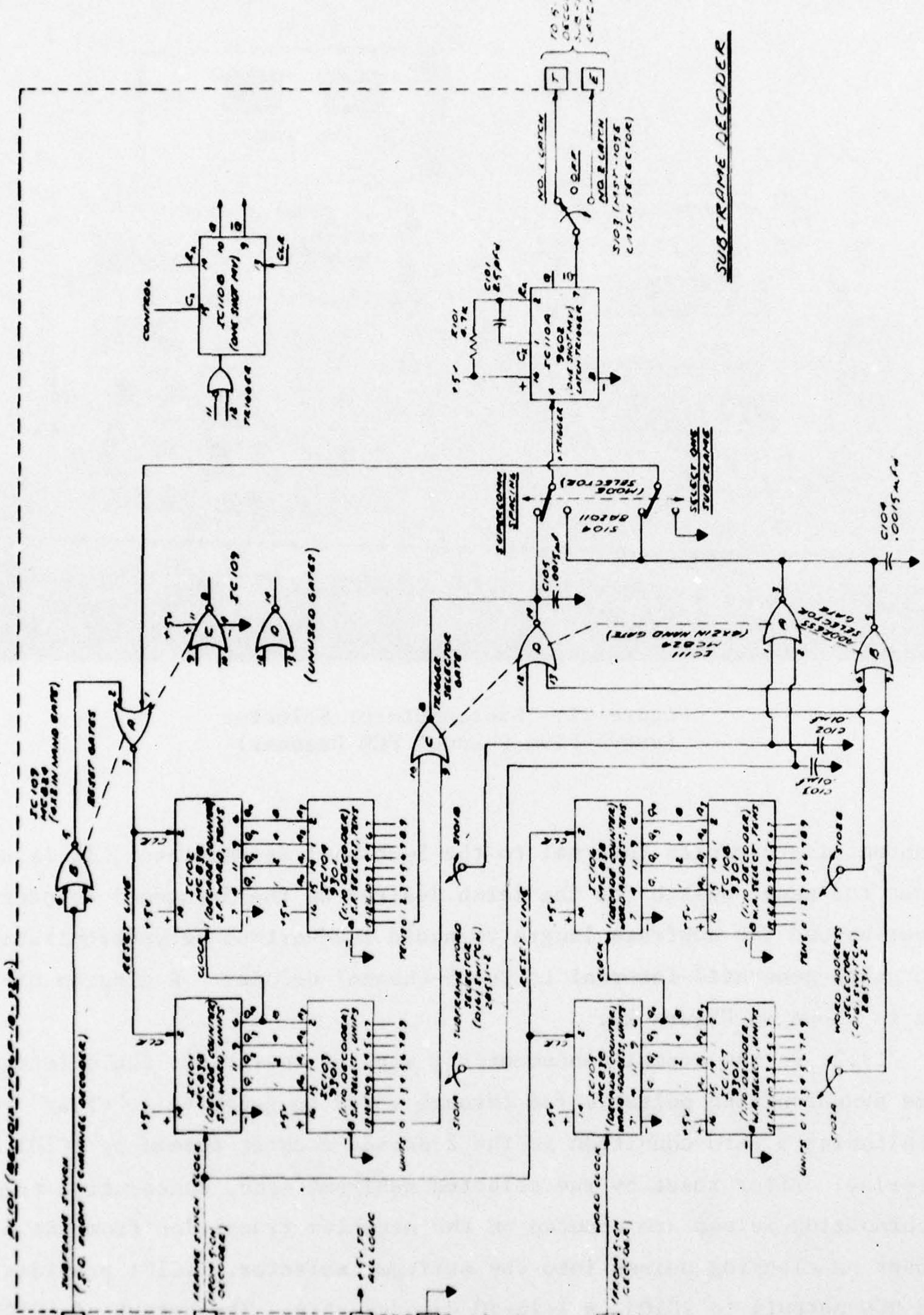


Figure 22. Subcomm Selector and Decoder

counter chips are fed into the associated "units" and "tens" decoder chips, IC103 and IC104. Since IC101 and IC102 have been cleared to zero by the selected subframe sync pulse from the master unit, their zero outputs combined by IC111C provide an enabling signal to one contact of S104 in the "super-subcomm" spacing mode. In the other "Subcomm Selector" mode, two two-digit decimal switches, S101A and B, permit selection of any desired frame within the sub-comm sequence. The "units" and "tens" output signal selected from the 1-in-10 decoder chips are then fed through IC111A to derive a similar enabling signal at the time of the selected subframe, which is fed to S104 again.

If the system is being operated in the "Super-Subcomm" mode with S104, the "00" indication is fed to IC1110A as a one-shot for a trigger, and the $\overline{Q}$ output from this one-shot is fed through S103 to the selected latch within the 5-channel decoder, thus synchronizing that latch first with the reset pulse and then again with a series of samples, spaced by the number of words indicated by selection of the subframe "supercomm spacing" switch. The output trigger from IC110A may then be fed to either Latch 1 or 2 of the associated 5-channel unit and will synchronize that channel with evenly-spaced supercommutated data within the selected subframe, each time the selected signal comes up. At the same time, the repeated data (at word spacing frequency from S101A and B) is combined and fed back through IC109A as a reset signal to resynchronize the decade counters (IC101 and IC102) at zero, thus permitting successive pulses to be counted out as evenly-spaced latches to the decoder.

The slaved synchronization pulse which is fed as a clock input to the subframe selector is also fed in as a clear signal to decade counters IC105 and 106. The associated word clock signal from the 5-channel decoder is then counted by IC105, the "units" counter and IC106, the "tens" counter, in the same manner previously described for the subframe selector. The net result is that words displaced within the minor frame by the indicated word address will be selected as the subcommutated word to be examined. Again, the parallel address lines (in 1, 2, 4, 8 BCD) from each decade counter are fed to IC107, a "units" 1-in-10 decoder and IC108, a "tens" 1-in-10 decoder. Switches 102A and B permit selection of "units" and "tens" as the word address, which are then combined in IC111B to obtain an enable gate to S104.

In the "supercomm spacing" mode of operation, this signal is used through IC109A to reset the decade counter for the subframe selector at the time of occurrence of the word for which subcommutation is desired. In the "select

one subframe" mode, this same signal is used to trip one shot IC110A and provide the desired latch signal to the selected latch within the five-channel decoder. (Note that, in the "select one subframe" mode of operation, reset of the frame counter IC101 and 102 is accomplished only by the frame synchronizing signal from the 5-channel decoder, since one section of S104 grounds the input to IC109A.)

A total of four units of this design have been built, thus providing the auxiliary subcommutator capability to all of the 5-channel PCM decoders available for support service under this contract.

7.8 Other Miscellaneous GSE Developments

In the course of services provided under this contract, a number of miscellaneous items of general utility in extending the capability of ground support equipment have been provided, either through modification of existing equipment or by additions to the supply of equipment available for support. These are miscellaneous in nature and have included obvious modifications of control consoles, to establish compatibility with the various payload support systems built up under this contract. Also included were such general support items as signal conditioning and interface equipment, low pass filters for FM discriminators, and S-band multicouplers.

7.8.1 In order to extend the usefulness of the AFGL-owned DCS-40 PCM decommutation system, a number of replacement clock cards were built up to extend the range of frequencies for PCM bit rates with which this equipment could be used. Such cards were constructed as duplicates of the original equipment with component modifications as desired to provide the bit rates required for use for various systems.

7.8.2 Data conditioning operational amplifiers, with the capability of DC-offset and "inverted" or "normal" operation were added to portable ground station equipment, using the same circuit described in connection with the multiplex box, C99TR12. These permit various input signals at the launch support point to be inverted and translated, to obtain the proper amplitude and polarity signals for operation of auxiliary equipment during field support missions.

7.8.3 In order to extend the usefulness of both manual and autotrack antenna systems when used in support of vehicles carrying more than one downlink for the telemetry signal, a number of S-band multicouplers were built up

during the course of this contract. These units are typically constructed from a commercial S-band preamplifier, in conjunction with an S-band power divider and an internal power supply. The basic circuitry involved was made an integral part of the control consoles for the TRATEL and Minitracker systems; when it became obvious that these units would provide extended capability in driving outboard receivers from both manual and autotrack antennas, four additional units of this type were constructed. Figure 23 (OSU A99SM01) is typical of the units so constructed for this purpose.

An Avantek model AM-2302-N S-band preamplifier is used as the basic element for the multicoupler system. This unit has a noise figure of approximately 3.5 db, accepts a relatively wide range of input signal levels, and provides coverage from 2200 to 2300 MHz, flat to 0.3 db, with a gain of approximately 23 db. Power required is +15 volts dc at only 40 milliamperes, and is provided from a commercial power supply, Power Mate Model MM-15A. The S-band preamplifier output signal is then fed as input to an Avantek Model PD-104-N power divider, which provides four decoupled S-band output signals from each such preamplifier, each suitable for driving an associated receiver. Units have been assembled into small cases for convenience in use; the multicoupler is normally installed at the console position and permits the low-loss RF cable from the associated external antenna to drive up to four receivers without undesirable interaction.

Two units of this type were rack mounted and installed within the RF patch system of the AFGL instrumentation van, when revising this system for BAMM support as described in section 6.7. Two additional units remain available for general purpose use in ground support activities.

7.9 Mass Spectrometer Calibration Interface

In connection with calibration of some of the mass spectrometer payloads flown aboard some of the rockets which carried the OSU support systems, a need existed for combining the payload digital output data with certain auxiliary data, then interfacing the system with a PDP-11 computer at the AFGL facility, for calibration and checkout of the scientific instrument.

7.9.1 Requirements for this purpose were to insert within an existing serial data stream (which originated within the instrument) the time (in a 12-bit binary code configuration) and a 12-bit digital word of auxiliary data, to be processed by the computer in performing the calibration function. The

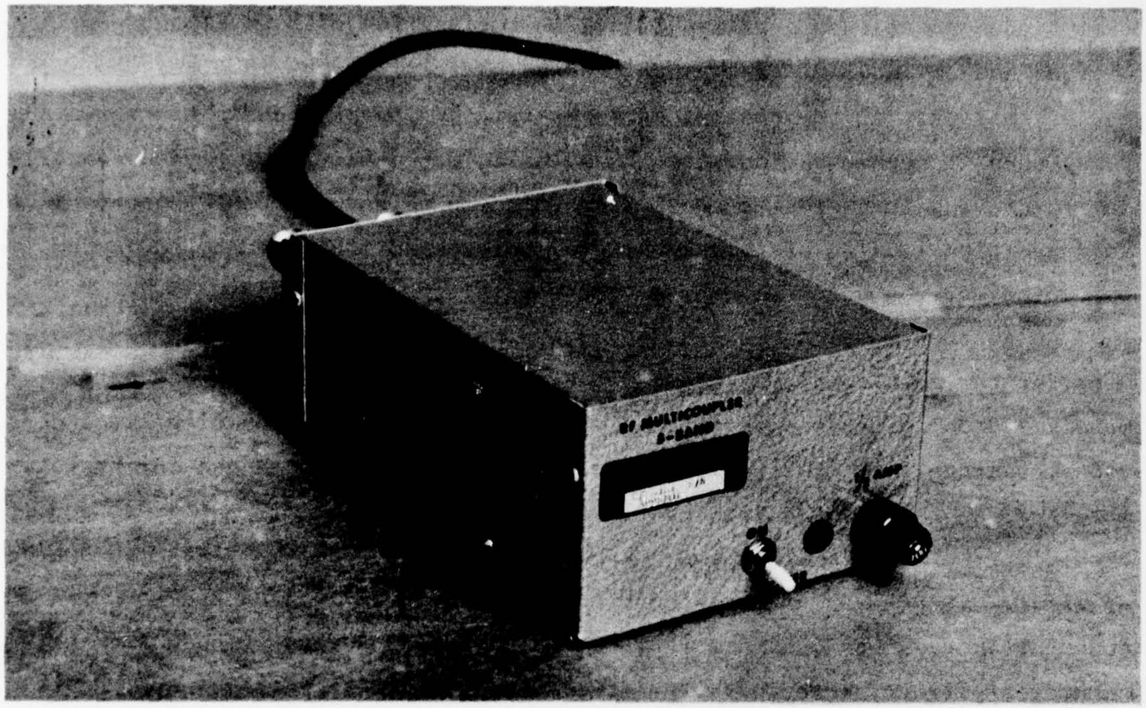


Figure 23. S-Band Multicoupler

data available from the instrument for this purpose consisted of a 2000 bit per second stream of 40 bits of digital data, followed by a stream of 24 zeros where no data existed. An interface unit was then required to operate in conjunction with this data stream to insert the required 24 bits of information at the appropriate time to generate a 64-bit frame of both data, time, and supporting information, for processing by the PDP-11 when calibrating the mass spectrometer instrument. The circuit devised for this purpose is shown in Figure 24 (C38PK01).

7.9.2 Clocking at 2000 per second was supplied from system being calibrated. IC102 was connected to count this down to establish the 64-bit frame length. Every 64th clock pulse is fed through OR-gate IC101C as a reset pulse to establish the 64-bit frame count and simultaneously reset IC103A, a set-reset flip-flop, in order to regenerate the required timing after 40 more bits of digital data input. The "8" count and "32" count from IC102 are combined in AND-gate IC106A and used as a "set" pulse to IC103A, thus generating gate pulses at Q1 and $\overline{Q1}$ outputs of this flip-flop.

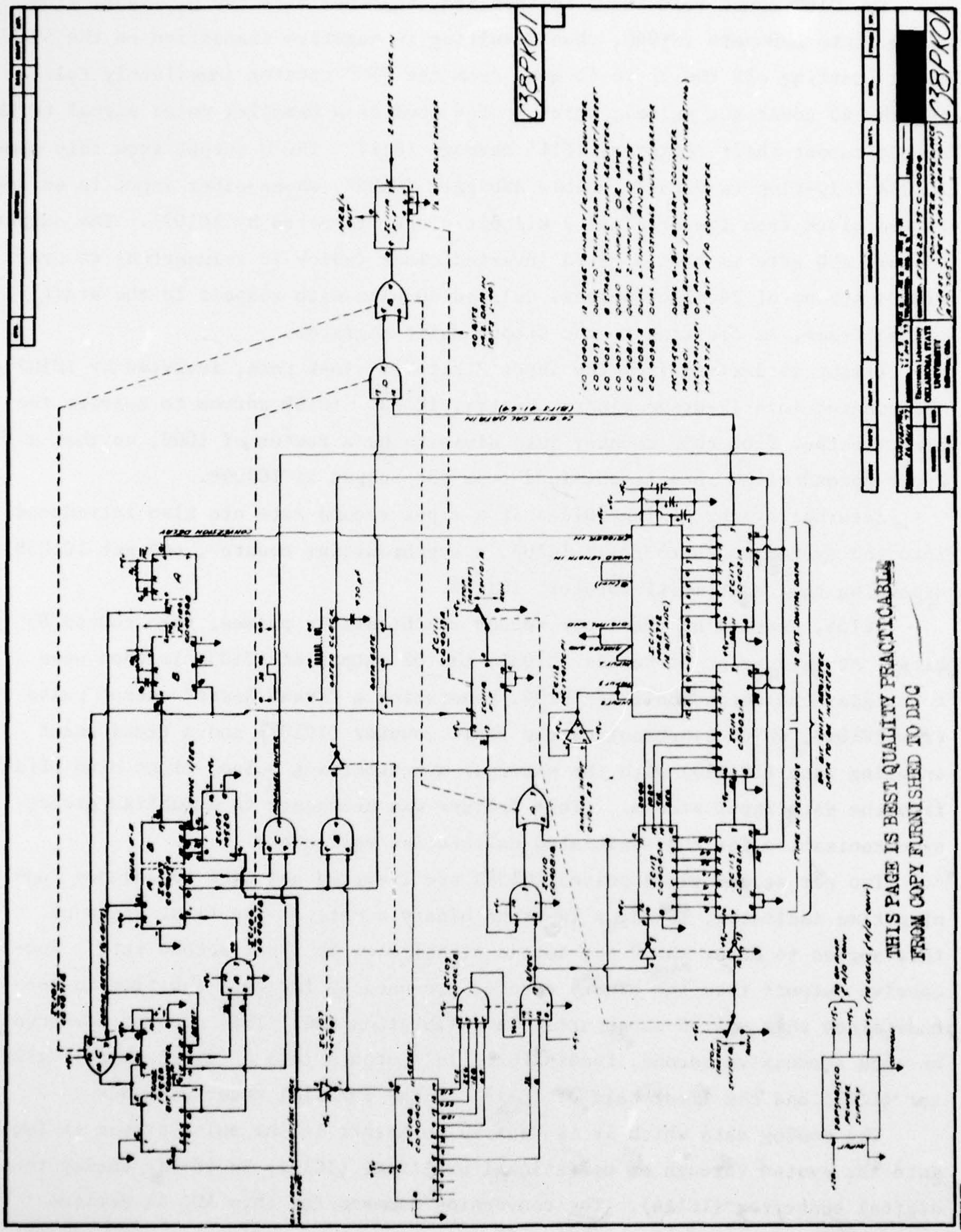


Figure 24. Mass Spectrometer Calibration Interface

The "16" count from IC102 is then fed, together with the $\overline{Q}_1$ signal from IC103, into AND-gate IC106C, thus resulting in negative transition on the 40th count (cutting off the 32 to 48 gate from the "16" counter immediately following the 40 count set pulse), which is fed down as a parallel enter signal to the 24-bit output shift register, IC115 through IC117. The Q output from this same IC103A flip-flop is used to enable AND gate IC106B, whose other input is an inverted clock from the original 2 kilobit clock (inverted by IC107). The output of this AND gate is then a gated inverted clock (which is reinverted) to provide a stream of 24 clock pulses, delayed 40 bits with respect to the start of the frame, as clocking to the output shift register.

Timing is derived from the input 2 kilobit clock rate, inverted by IC107 and counted in a 12-stage binary counter, IC108. IC109 serves to convert the binary output from this counter into division by a factor of 1000, so that a 2 per second clock rate is obtained from the output of IC109B.

External synchronizing pulses at a 1 per second rate are also introduced into the system so as to reset IC105, a synchronizing counter, and set IC103B, disabling the reset multivibrator, IC104B.

IC105, enabled by the 1 per second synchronizing pulses, then counts 8 bits. At this point it resets IC103B; the Q2 output of IC103B is then used to trigger the second half of IC104, generating a "Frame Reset" output pulse from IC104B, which synchronizes the frame counter (IC102) and a timed reset enabling gate (IC111A) with the external synchronizing pulse, eight bits offset from the data input stream. (This feature was necessary to establish proper synchronization for the associated calibration equipment.)

Two per second clock pulses IC109B are inverted and used to advance running time indicator, IC113, a 12-stage binary counter. The first stage of this serves to count the 2 per second signal down to 1 per second rate. Successive outputs from the binary counter are used to indicate the time in seconds since this system was started on calibration run. This counter advances on each successive second, feeding parallel outputs into a 12-bit shift register (IC115 and the first half of IC116) on the parallel enter commands.

The analog data which it is desired to insert in the pulse stream is fed into the system through an operational amplifier (IC112) to 12-bit analog-to-digital converter (IC114). The conversion command for this ADC is derived from the Q1 signal of IC104A, which is triggered by the frame counter (IC102). The 12 output lines from the analog-to-digital converter (IC114) are then fed

to the remaining 12-bits of storage register (half of IC116 and IC117), thus filling the 24-bit shift register address capability.

In order to insert these 24 bits at the proper point in the data stream, the parallel enter command to this static shift register is derived on the 40th pulse within the frame, as generated on I106C output line. Gated clock pulses from the two kilobit external clock are fed into the shift register by the inverted output from IC106B, thus clocking this shift register data through and inserting it into the blank portion of the digital input frame at the desired point within the sequence. OR gate IC101B serves as a switch for this purpose, feeding through 40 bits of mass spectrometer data, then inserting 24 bits of calibration data during the 24 blank spaces. The output signal from the system is then fed through a flip-flop (IC111A) and clocked through as an NRZ-Level output signal from the 2-kilobit clock, providing a half-bit delay in the output signal with respect to the input signal.

Switch 101A is used to start a calibration run. In the "reset" mode, 5 volts is applied to the frame sync flip-flop and to the elapsed time counter chips (IC111B and IC113). The 5 volt signal is also OR gated through to IC108, thus holding the clock pulse counter in a reset mode. When the switch is thrown to the "run" position, this reset pulse is removed, permitting IC108 to start counting clock pulses, IC113 to count the half-second timing pulses, and enabling the entire system. The first bit of the IC115 shift register receives its input through an inverter chip driven by SW101B, the run switch, in order to indicate by the position of a flag bit that a calibration run is under way.

8.0 SUMMARY OF RESULTS

Because the primary objective under this contract was to supply engineering support services to an on-going program of rocket research in the upper atmosphere, a specific conclusion regarding the outcome of contractual activities is difficult to draw, beyond the broad generality of a numerical summary of the support activities provided.

8.1 Engineering Field Services

Field services under this contract not only encompassed planning conferences, coordination activities, and prelaunch test activities for the entire program assigned to Oklahoma State University during the 42 months of this

contract, but also included launch support activities for a total of 62 different payloads, launched from eight different launch sites within the United States and abroad. Tests and evaluations of developmental equipment were also accomplished in conjunction with some of these field support services, judging the performance of items developed for future application under this instrumentation program.

8.2 Construction Activities

Components and equipment were built and supplied as required in furtherance of the overall program, both for airborne payload usage, and for specialized ground support services.

8.2.1 Airborne equipment was supplied for a total of 33 different rocket payloads during the life of this contract. This portion of our work included not only the normal payload support systems which combined telemetry, trajectory, and control systems for an external instrument, but also a great deal of specialized pulse code modulation equipment which was developed, qualified, and custom built for application to the specific payload requirements. Of major significance in this area of our work has been the development of state-of-the-art coding equipment for the Multi Spectral Measurement Program and the Balloon Airborne Mosaic Measurement program, both of which had unique requirements which could not be satisfied by commercially available equipment. A similar encoder is under development for application to the Infrared Background Sensor program under a following contract. A number of devices for incorporation in payloads were also developed and constructed for applications which included ranging through telemetry reception, PAM commutation, telemetry calibration, and other miscellaneous interface requirements.

8.2.2 Ground support equipment (beyond the specialized equipment involved in tracking and trajectory determination) was provided for PCM decoding, PAM decommutation, and to assist in the normal housekeeping functions in ground station operation and field support activities. Specialized PCM decoding equipment was developed both for a gyro reference system and the falling sphere experiment; existing general purpose PCM decoders were also modified to permit greater flexibility and higher speed operation. Five-channel PCM decoder modification included supply of a subcommutator selector, to extend the usefulness of the existing equipment. A single-channel PAM decommutator was constructed for the AFGL instrumentation van, together with a

multiplex/voice box to facilitate recording the station housekeeping data on magnetic tape. A number of minor items were provided when circumstances required their use. A special digital electronic circuit was developed to permit automated calibration through interface with a PDP-11 computer on mass spectrometer payloads.

8.3 Tracker and Trajectory Equipment

In a continuation of the developmental program initiated under earlier contracts, tracking and trajectory equipment was refined and supplied for ground support activities applicable to remote launch facilities where existing telemetry and tracking equipment was not available. The TRATEL versions of the autotrack antenna system were rebuilt to a new configuration after fire damage, and now exhibit improved performance capability. In addition, a lightweight portable Minitracker which disassembles for easy shipment was developed to extend autotrack antenna capability and this antenna system provided circuitry for further improvement and simplification of the earlier TRATEL equipment. Experience gained with the TRATEL and Minitracker equipment was also of significance in making modifications to an existing tracker belonging to AFGL. The TRADAT system developed earlier for use with the TRATEL systems in providing full trajectory data was also updated during this contract. One auxiliary TRADAT system was built and installed in the AFGL telemetry support system. Auxiliary equipment of usefulness with the tracker and trajectory system has included both digital line printers and a dedicated microprocessor for conversion of trajectory elements to more usable form, and to supply hard copy of trajectory data in real time or by tape playbacks.

8.4 Developmental Work

Development initiated under this contract has included expansion of the concept of ranging through telemetry to its use with pulse code modulated telemetry systems, and the additional capability for command control of payloads through the uplink used in the TRADAT ranging system. A study and some hardware decisions have resulted; implementation of the design will be continued under the following contract.

LIST OF REFERENCES

1. Buck, Richard F. & Fike, R. M.: Support Services for I.R. Rocket Payloads. (Final Report to F19628-72-C-0172). Research Foundation, Oklahoma State University, Stillwater, Oklahoma 74074 (AFGL-TR-76-0031; 31 March 1976).

2. Staff Authors: Research Rocket Instrumentation. (Final Report to F19628-72-C-0224). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL 70-0322; April 1970).

3. Buck, Richard F. (with Claude M. Gwinn, R. D. Mitchell, Joe B. Zinn): Engineering Support Services, Research Rocket Instrumentation. (Final Report to AF 19(628)-4993). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-68-0352; February 1968).

4. Buck, Richard F. (with A. D. Costner, C. M. Gwinn, R. M. Fike, D. R. Lynch, P. R. Park, J. R. Slaughter, & J. B. Zinn): Engineering Support Services, Instrumentation for Aerospace Research Program. (Final Report to F19628-70-C-0147). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-72-0447; 15 July 1972).

5. Gwinn, C. M.: Design of a PCM Telemetry Encoder for Balloon Altitude Mosaic Measurements. (Technical Report No. 1 to F19628-75-C-0084) Electronics Laboratory-DETA, Oklahoma State University, Stillwater, Oklahoma (April 1978).

6. Buck, Richard F., Gwinn, C. M. & Fike, R. M.: Instrumentation for Research Rockets. (Final Report to F19628-72-C-0139). Research Foundation, Oklahoma State University, Stillwater, Oklahoma 74074 (AFCRL-TR-75-0216; 30 April 1975).

7. Fike, R. M.: Single Channel Monopulse Converter (Scientific Report No. 1 to F19628-75-C-0084) Electronics Laboratory, Research Foundation, Oklahoma State University, Stillwater, Okahoma (AFGL-TR-76-0085; March 1976).

8. Skach, Leonard J.: S-Band Radiosonde Transmitters (Scientific Report No. 3 to F19628-72-C-0139) Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-TR-73-0743; November 1973).

9. Gwinn, Claude M.: A Synchronizing Circuit for PAM Decommutation. (Scientific Report No. 1 to F19628-72-C-0139) Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-TR-0715; October 1973).

10. Lamb, T. M.: A State-of-the-Art Pulse Amplitude Decommutator Design. AFCRL/LCS Report, Hansom Air Force Base, Massachusetts (March 1973).

11. Fike, R. M.: Trajectory Determination and Telemetry Receiving System Evaluation. (Scientific Report No. 2 to F19628-75-C-0084) Electronics Laboratory-DETA, Oklahoma State University, Stillwater, Oklahoma (AFGL-TR-76-0276; November 1976).

APPENDIX A

TO

FINAL REPORT

Contract F19628-75-C-0084

MINITRACKER IA

Portable S-band Automatic Tracking Antenna System

R. M. Fike

(From Technical Report No. 2,
F19628-75-C-0084)

SUMMARY

Minitracker IA was designed to be a highly portable S-band autotrack antenna system to be used to receive telemetry data from sounding rockets launched at remote launch sites where fixed-site telemetry trackers are not available. Minitracker uses a single-channel monopulse RF feed with its four-foot parabolic reflector. The tracker can be disassembled into small sub-assemblies that are packed in plastic cases so that it can easily be shipped by commercial air freight. The controls consist of an 8 3/4"x19"x19" control console and an S-band receiver. The OSU Tradat system can be used with Mini-tracker to provide trajectory data.

This report consists of a Minitracker system description, set up procedures, and operation procedures. The system description includes specifications and simplified circuit descriptions. The set up procedures include everything necessary to make the system operational, from site selection to electronics set-up. The operation procedures consist primarily of aids in autotrack acquisition of target vehicles.

TABLE OF CONTENTS

MINITRACKER IA PORTABLE S-BAND AUTOMATIC
TRACKING ANTENNA SYSTEM

TABLE OF CONTENTS (CON'T)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

The Minitracker was developed by the Oklahoma State University (OSU) Electronics Laboratory for the Air Force Geophysics Laboratory (AFGL). It was designed to receive telemetry data from sounding rockets launched at remote launch sites where fixed site telemetry trackers are not available. If trajectory data is required, the OSU Tradat system can be used with the Minitracker to provide trajectory data.

OSU S-band tracker development began in 1968 with the conversion of an AN/GMD-2 into an S-band tracker.[1] Next, a T-9 fire control radar set was converted into an S-band tracker.[2] Both of these were conical scan systems. OSU then developed two single channel monopulse trackers using Scientific-Atlanta, Inc. components. These trackers were named Tratel I and II.[3,4,5,6] OSU subsequently developed its own monopulse autotrack system[7] and tracker control system.

2.0 SYSTEM DESCRIPTION

Minitracker is very small, as can be seen in Figure 1. It can be dismantled into small, lightweight subassemblies, as shown in Figure 2, so that it can easily be handled and packed. The subassemblies are packed in lightweight plastic cases as shown in Figure 3 so that the Minitracker can be shipped by commercial air freight. Minitracker subassembly sizes and weights are in Table 1. The four main subassemblies are numbered in Figure 4.

Table 1. MINITRACKER IA SUBASSEMBLY SIZES AND WEIGHTS

Box	Item	Wt (Lbs)	Shipping Wt (Lbs)	Volume (Cu Ft)
1	Dish	46.5	94	12.2
2	Legs & RF Feed	95	145	11.2
3	Riser	90.5	116	7.4
4	Elevation Head	64	90	5.6
	Tracker Weight =	296		
5	Control Console	47	67	4.1
6	Receiver	45	67	4.1
	Controls Weight =	92		
7	Cables	70	100	4.1
	Grand Total	458 lbs	679 lbs	48.7 Cu Ft

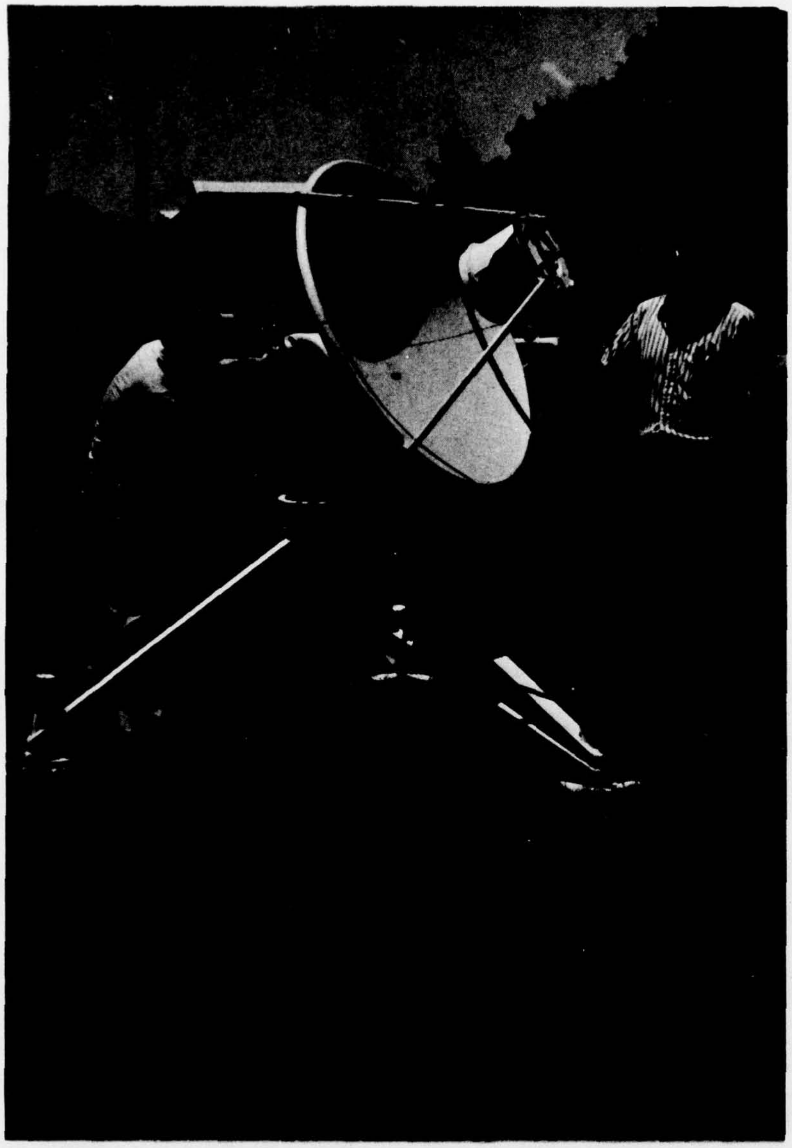


Figure 1. Minitracker IA

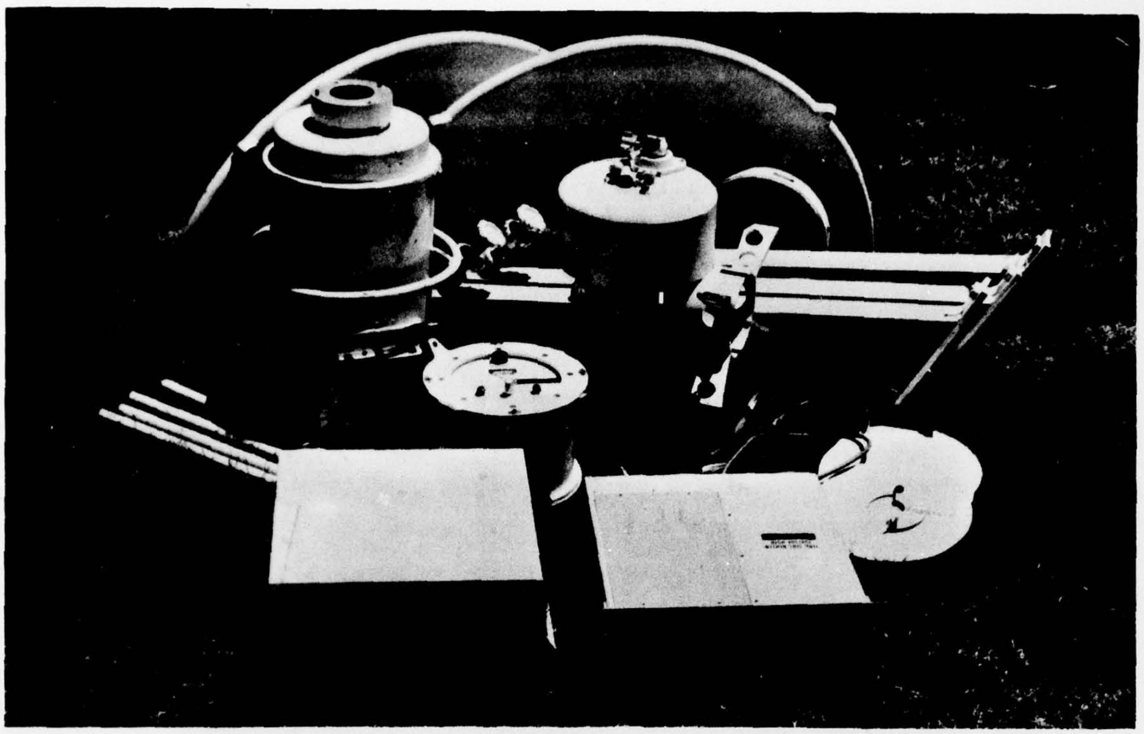


Figure 2. Minitracker IA Disassembled

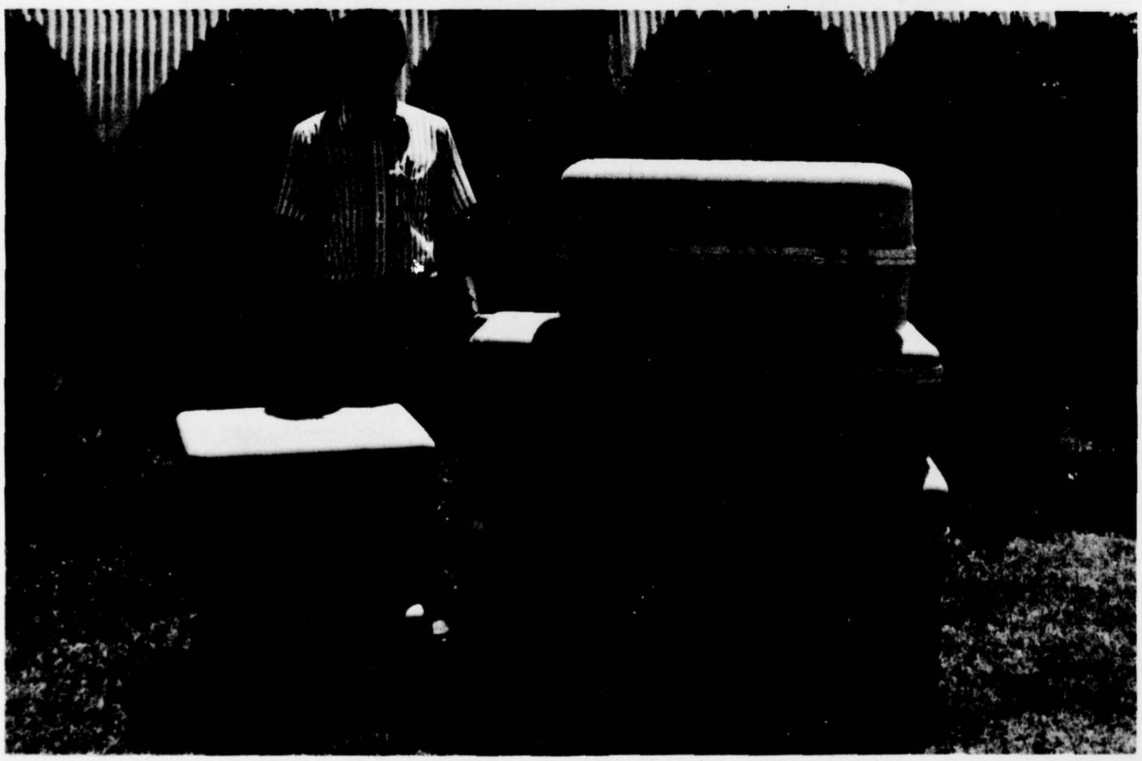


Figure 3. Minitracker IA Packing Cases

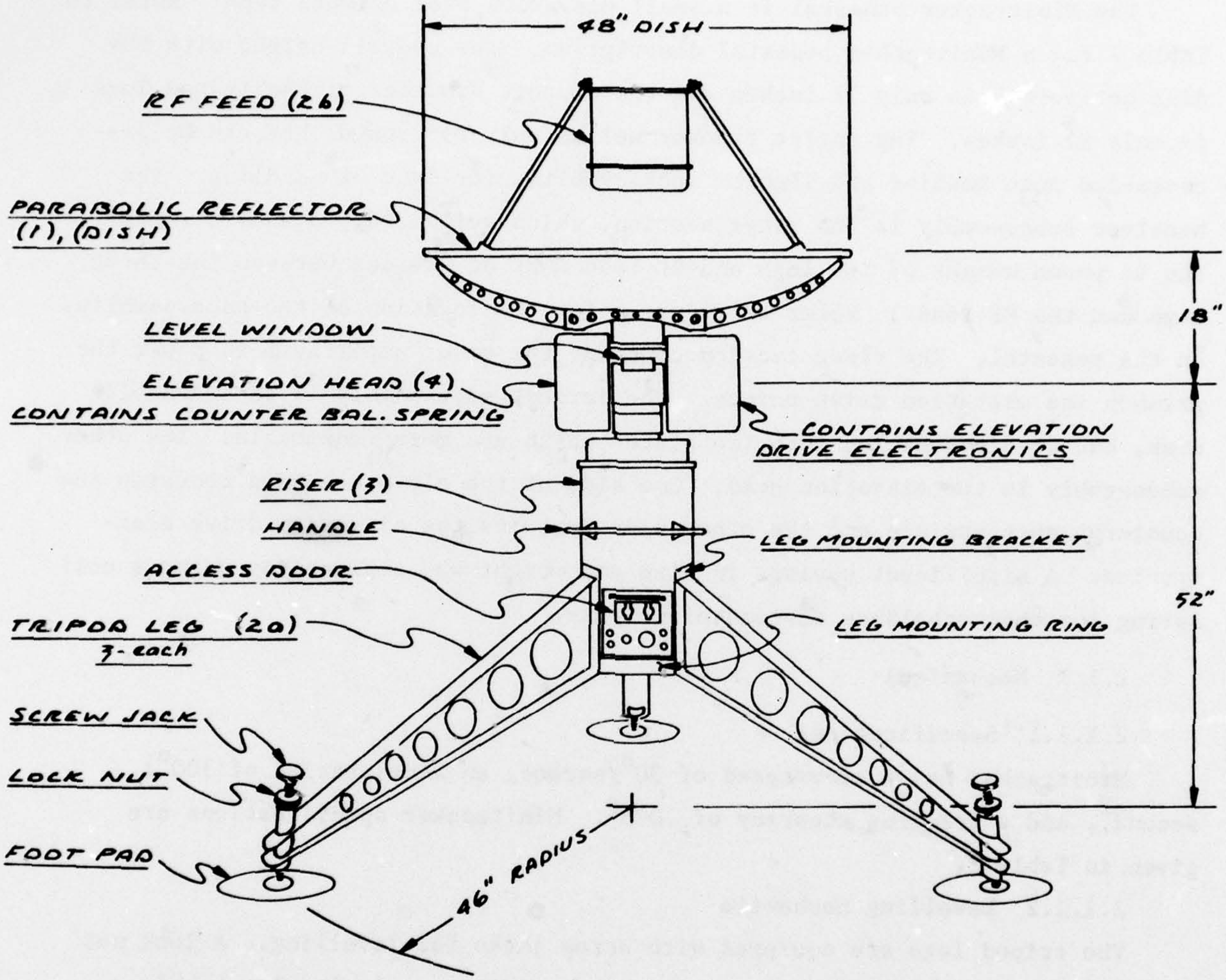


Figure 4. Minitracker IA Pedestal Parts

The RF feed uses the OSU-developed single channel monopulse system, as opposed to a conical scan system, which is subject to poor tracking and even loss of track when used to track spin-stabilized rockets. The control console is completely self-contained in one chassis, including azimuth and elevation displays. An S-band receiver is the only other piece of equipment required.

2.1 Pedestal

The Minitracker pedestal is a small elevation over azimuth type. Refer to Table 2 for a Minitracker pedestal description. The overall height with the dish horizontal is only 77 inches and the support diameter of the tripod legs is only 92 inches. The entire tracker weighs only 296 pounds but can be disassembled into smaller and lighter subassemblies for ease of handling. The heaviest subassembly is the riser section, which weighs 90.5 pounds. (Note: The 95 pound weight of the legs and RF feed must be divided between the three legs and the RF feed.) Refer to Figure 4 for the location of the subassemblies on the pedestal. The riser section contains the power amplifiers to power the azimuth and elevation drive motors. The largest subassembly is the parabolic dish, but it disassembles into two pieces which are more manageable. The other subassembly is the elevation head. One side of the elevation head contains the counterbalance springs and the other side contains the elevation drive electronics. A significant savings in size and weight was achieved by using a coil spring for counterbalance instead of weights.

2.1.1 Mechanical

2.1.1.1 Specifications

Minitracker has a slew speed of 30^{o}/second, an acceleration of 100^{o}/second^{2}, and a tracking accuracy of $.075^{o}$. Minitracker specifications are given in Table 3.

2.1.1.2 Levelling Mechanism

The tripod legs are equipped with screw jacks for levelling. A lock nut is provided to secure the jacks in the level position. A circular bubble level (visible through a plexiglass window in the top of the elevation head) is used to level the tracker.

2.1.1.3 Assembly

The Minitracker is assembled using only one size captive bolt: 3/8". Thus, only one wrench is required for assembly and there are no loose bolts to get lost. Refer to section 3.2 for detailed assembly instructions.

2.1.1.4 Boresight Telescope

A 3-to 9- power zoom boresight telescope is attached to an adjustable mount on the end of the elevation head. A hole in the dish allows visibility.

2.1.1.5 Gears and Bearings

The bearings are a double-shielded, prelubricated type and the gears are

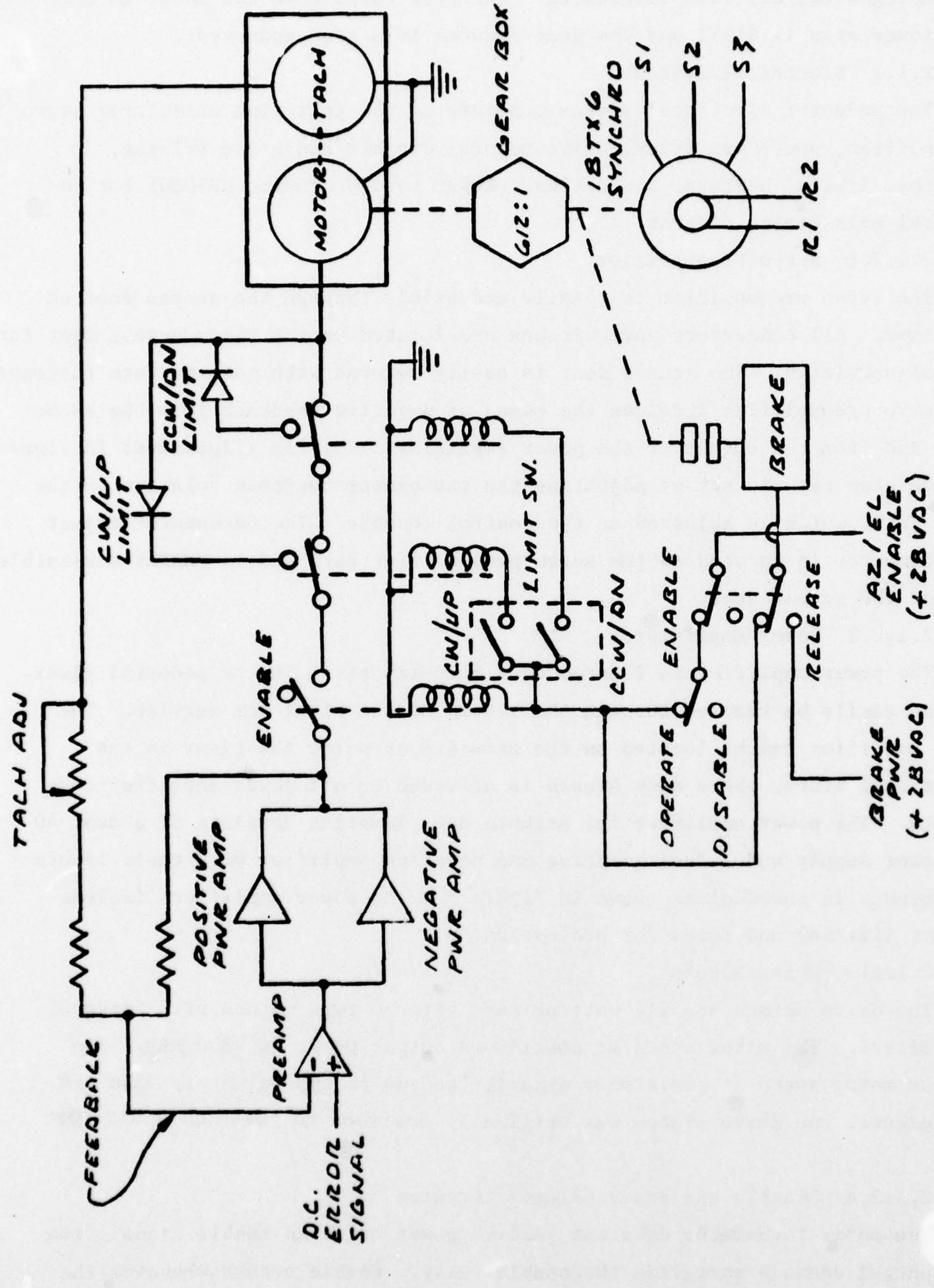


FIG. 5 MINITRACKER IA PEDESTAL SIMPLIFIED SCH.

oil impregnated, dry film lubricated. The gear ratio from the motor to the positioner axis is 612:1 and the gear reducer is a spur gear type.

2.1.2 Electrical System

The pedestal electrical system consists of the following circuitry: servo preamplifier, power amplifier, drive motors, disable and brake release, synchros, limits, heaters, and cables. Refer to OSU drawing D95DE01 for the pedestal main wiring diagram.

2.1.2.1 Servo Preamplifier

The servo preamplifier is readily accessible through the access door on the riser. All connectors and switches are located on the riser access door for ease of servicing. The access door is easily removed with quarter turn fasteners. The servo preamplifier provides the means of negative feedback from the tachometer and from the output of the power amplifier. This is illustrated in Figure 5. The slew rate is set by adjusting the tachometer feedback relative to the servo gain, which is adjusted at the control console. The tachometer adjust potentiometer is located on the servo preamplifier card and is easily accessible through the access door.

2.1.2.2 Power Amplifier

The power amplifier is located on a circular plate in the pedestal riser and can easily be removed through the bottom of the riser for service. The power amplifier can be located on the ground just below the riser in the operational state, where easy access is afforded to all power amplifier components. The power amplifier for azimuth and elevation consists of a dual 40 VDC power supply and a dual positive and negative amplifier with their inputs and outputs in parallel as shown in Figure 5. The power amplifiers include current limiting and fuses for protection.

2.1.2.3 Drive Motors

The drive motors are 112 watt printed circuit type motors with integral tachometers. The motor speed at continuous output power is 2800 RPM. The maximum motor speed at positioner dynamic loading is approximately 3060 RPM. The pedestal and drive system was originally designed to position a six foot dish.

2.1.2.4 Disable and Brake Release Circuits

The motor tachometer does not receive power until an enable signal from the control console energizes the enable relay. Enable occurs whenever the controls are set in one of the operating modes (autotrack, manual, or slave). Power is removed from the motor when the disable switch or one of the brake release switches are engaged. The disable switch and brake release switches are

located on the access door. The disable switch is a safety device to disable the tracker while someone is working at the pedestal. The brake release switches allow the pedestal to be slewed by pushing the dish by hand. The brakes are engaged in the standby and power off modes. This prevents the dish from being repositioned by wind gusts when in the standby or power off modes.

2.1.2.5 Synchros

There is an 18TX6 synchro geared to both the azimuth and elevation axes through antibacklash gears. The synchros provide the data for the azimuth-elevation angle digital displays in the control console.

2.1.2.6 Limit Circuitry

There is limit circuitry for both the azimuth and elevation axes, as shown schematically in Figure 5. The azimuth limit is set to allow an azimuth slew of $\pm 184^{\circ}$ before the tracker drive is disabled. The limit switches are in a precision cam mechanism geared to the azimuth axis. The circuitry disables the drive in the direction it was slewing when it hit the limit, but allows it to be slewed in the opposite direction. This is accomplished by using the diodes shown in the schematic. Azimuth limit circuitry is added so that slip rings are not necessary and cables may be run through the elevation head without being twisted and damaged. The elevation limit circuitry is identical to the azimuth limit circuitry. The elevation limits are set for -3° to $+183^{\circ}$. A rubber padded mechanical bumper is provided to stop the elevation travel when the elevation axis coasts through the electrical limit during high slew speeds.

2.1.2.7 Heaters

Silicone rubber heaters are included in the pedestal to allow operation in Arctic conditions. A 100 watt heater is in the riser section and a 50 watt heater is in each side of the elevation head and in the feed, for a total of four heaters. Each heater is controlled by an OSU-developed zero voltage switching thermoswitch, which is adjustable between 32°F and 50°F. The zero voltage switching thermoswitches prevent undesirable transients during heater switching. These thermoswitches also provide an analog temperature indication to the heater monitor circuit in the console. OSU drawing C95DC08 may be referred to for further details of the thermoswitch circuitry.

2.1.2.8 Cables

The cables required to operate the pedestal are one multiconductor control cable, one power cable, one ½" superflexible RF cable for S-band reception, and one RG-8 RF cable for calibrating the RF system. All cables are

100 feet long. There is provision for one additional RF cable when the Tradat ranging system is used with Minitracker. This cable is for the ranging transmitter. Refer to OSU drawing B95DH01 for further cable details.

Table 2. Minitracker IA Pedestal Description

Physical	
Height to Elevation Axis	52 inches
Overall Height (Dish Horizontal)	77 inches
Base Diameter (Tripod Legs)	92 inches
Material	Aluminum
Hardware	Stainless Steel
Total Weight	296 pounds
Stow Locks	Not required
Hand Cranks	Not required
Brakes	Azimuth & Elevation
Phone	Phone connector for communication from pedestal to console.
Power Gear Train	Spur Gear (612:1 reduction)
Boresight	3-9X Zoom telescope
Levelling	Circular bubble level, tripod screw jacks
Pedestal Configuration	Totally enclosed, elevation-over-azimuth, servo amp in pedestal.
Disable Switch	Disables pedestal for safety.
Azimuth & Elevation Brake Release Switch	Release brakes for manual movement.
Cables	One control, one power, one ½" foamflex RF, one RG-8 cal. (All cables 100 feet.)
AC Utility Outlets	Two weatherproof outlets
Counterbalance Assembly	100% (by coil spring)
Environmental	
Temperature	
Operation	-50°C to +60°C
Non-Operation	-60°C to +75°C
Humidity	100%
Wind	
Operation	40 MPH (Can be greater with tiedowns.)
Survival	120 MPH (with tiedowns.)
Salt Atmosphere	Coastal region
Rainfall	Tropics
Sand & Dust	Desert region
Altitude	0 to 10,000 ft.

Table 3. Minitracker IA Specifications

Azimuth

Velocity	30 deg/sec
Acceleration	100 deg/sec^2
Travel	$\pm$ 184^o
Motor Power	112 watts
Pointing Accuracy	.075^o RMS
Servo Bandwidth	1 Hz
Natural Resonance Frequency	7 Hz

Elevation

Velocity	30 deg/sec
Acceleration	100 deg/sec^2
Travel	-3^o to 183^o
Motor Power	112 watts
Pointing Accuracy	.075^o RMS

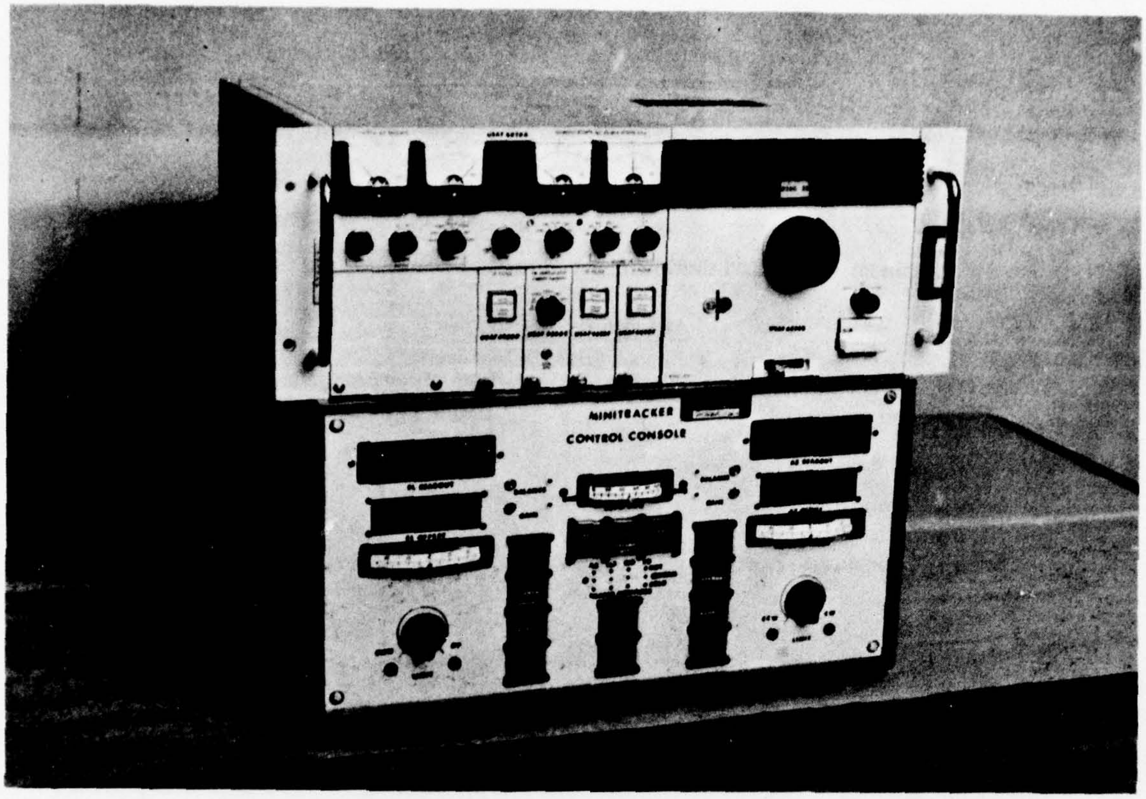


Figure 6. Minitracker IA Controls

2.2 Control Console

The Minitracker controls shown in Figure 6 consist of the control console and an S-band receiver. All control console switches are backlighted, labeled relay type pushbuttons. The pushbutton lighting is designed such that all green light is the normal operational condition for autotrack and any red lighted pushbutton is a non-operational condition for autotrack. The displays and controls on the left half control the elevation axis and the controls on the right half control the azimuth axis. Table 4 may be used in conjunction with the pictures of the front and rear panels (Figures 6 and 7) for an understanding of the controls, indicators and connectors and their locations. OSU drawing D95DC01 may be referred to for the control console main schematic.

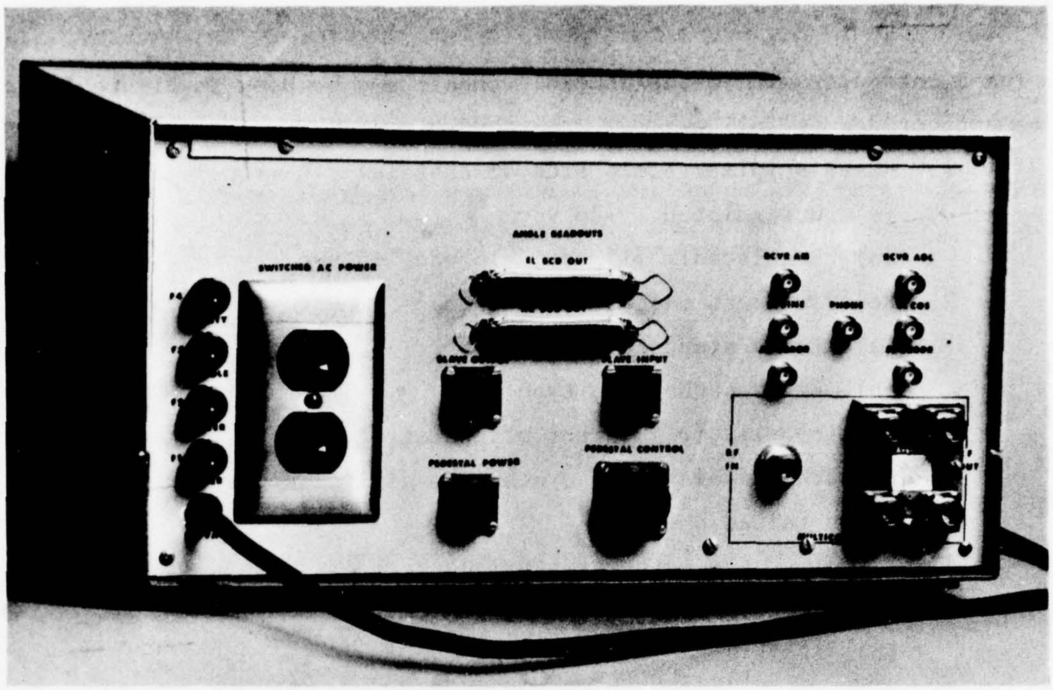


Figure 7. Minitracker IA Console, Rear Panel

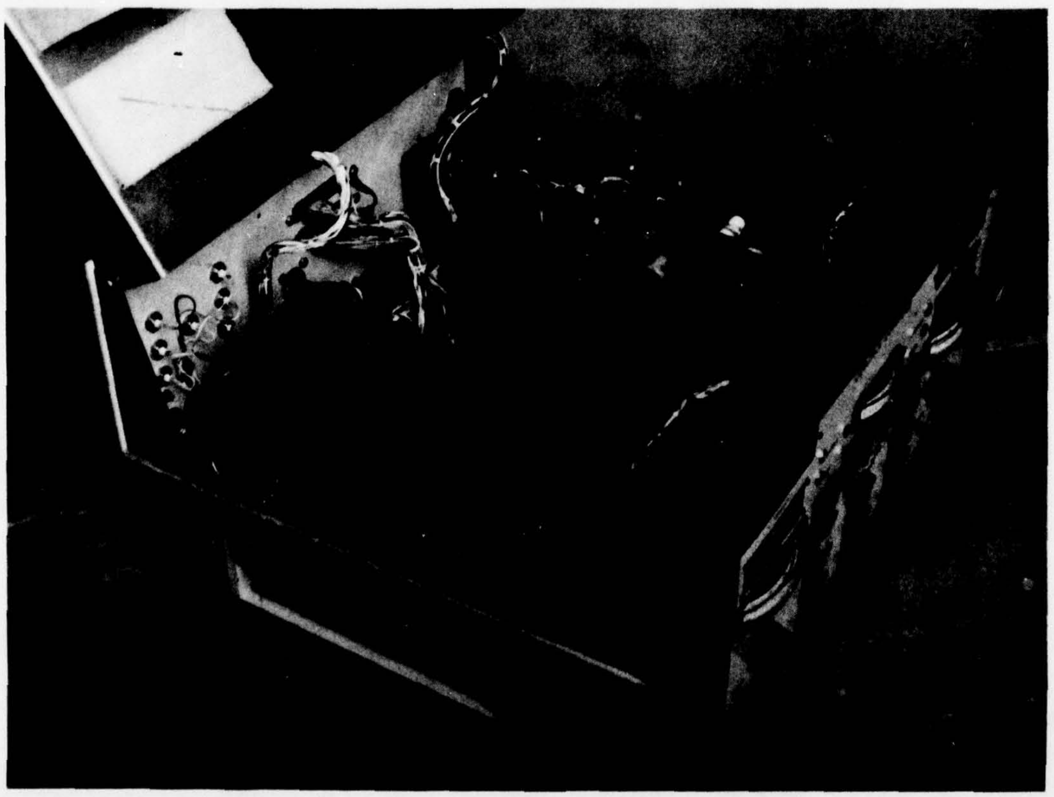


Figure 8. Minitracker IA Console Electronics

The electronics within the control console may be seen in Figure 8 and may be categorized as follows:

1. Power supplies (left side of chassis)
   (a) Unregulated: +28 vdc
   (b) Regulated: +15 vdc, -15 vdc, +5 vdc
2. Relays (front center of chassis)
   (a) Three standard type
   (b) Eight pushbutton type
3. Multicoupler (right rear of chassis)
4. Azimuth and elevation synchro to digital converter (on raised shelf)
5. Plug-in, wire wrap cards (right rear of chassis)
   (a) Azimuth digital offset
   (b) Elevation digital offset
6. Plug-in, printed circuit cards (right center of chassis)
   (a) Heater monitor
   (b) Scan code generator
   (c) Azimuth demodulation
   (d) Elevation demodulation
   (e) Divider (for secant correction)
   (f) Synchro to sine/cosine converter (for secant correction)
   (g) Manual command

A description of the console controls and their functions is given in Table 4, on the following pages.

Table 4. Minitracker IA Control Console Description

Size		8 3/4"Hx19"Wx19"D
Weight		47 pounds
Modes of Operation	(Azimuth or elevation may be independently selected by back-lighted pushbuttons.)	
Mode	Lamp Color	Condition
Standby	Yellow	System is energized, drive motor power is removed & brakes are applied.
Manual	Yellow	Pedestal is rotated using the manual rate knob.
Auto	Green	Antenna automatically tracks.
Slave	Yellow	For remote operation by addition of manual command unit or other slave operation.
Controls (All controls are back-lighted pushbuttons.)		
Power On/Off	Green	Initially energizes system in standby mode.
Mode Select		Standby, manual, autotrack, & slave for azimuth and elevation axis.
Heater On/Off	Green	For actuating thermal switch controlled heaters.
Preamp: On	Green	Energizes preamplifier.
Off	Yellow	
Feed: Calibrate	Red	Energizes RF switch in RF feed for calibrating RF system, or operating.
Operate	Green	
Azimuth: Normal	Green	Inverts Azimuth autotrack error signal for operation in "plunged" condition.
Invert	Red	
Indicators		
Digital Az and El Display		LED displays of Az & El angle to nearest 0.01°.
Az & El Error Meters		Displays Az & El autotrack error signals.
Signal Strength Meter		Displays receiver signal strength in db above noise.
Azimuth CW & CCW (LED)		Indicates CW or CCW limit.
Elevation Up & Down (LED)		Indicates up or down limit.
All Limit Indicators Illuminated		Indicates pedestal disable switch is actuated.
Both Elevation or Azimuth Indicators Illuminated		Indicates pedestal brake released in that axis.
Temperature Monitors (LED)		Green indicates normal; upper red lights indicate too hot; lower red lights indicate too cold in pedestal.
Front Panel Test Points		Az & El autotrack demod outputs (Balance & Gain)

Table 4 (Cont'd) Minitracker IA Control Console Description

Front Panel Adjustments	
Az & El Offset	Thumbwheel digiswitches for offsetting the angle readouts.
Az & El Balance	Potentiometer for balancing the demod amplifier.
Az & El Gain	Potentiometer for setting the demod amplifier gain.
Back Panel Outputs	
Power	Provides power to servo amps and heaters.
Control	Control cable to pedestal.
Az & El Angles	BCD Az and El angles
Az & El Error Signals (BNC)	Output of Az and El autotrack demods.
Multicoupler	4-port RF output (type "N").
Sin & Cos El (BNC)	From solid state secant correction module.
Utility 110 VAC	2 Utility outlets switched with console.
Phone (BNC)	For communication from console to pedestal.
Slave Out	Synchro outputs to "slave" another device.
Back Panel Inputs	
Power	Standard 3 wire 110 VAC
RF	From pedestal to multicoupler (type "N").
Receiver AGC (BNC)	From receiver to signal strength meter (0 to -10 VDC).
Receiver AM (BNC)	From receiver to demodulators
Slave Input	"Slaves" Minitracker to another device.
Secant Correction	Solid state sin/cos converter used with solid state divide circuit.
Power Supplies	All power supplies (+28, +15, -15, +5 VDC) are included in the console.

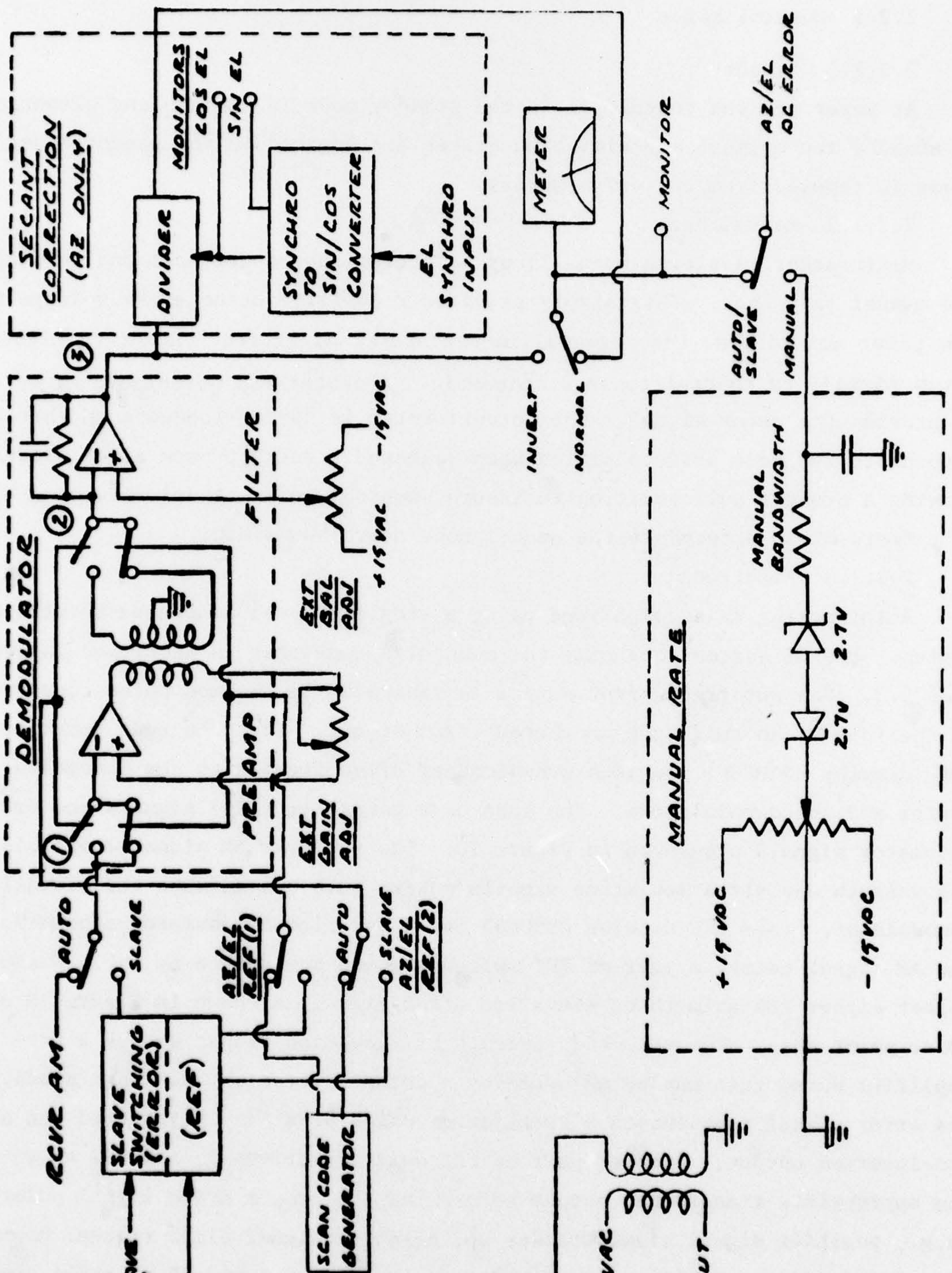


FIG. 9 MINITRACKER IA CONTROL CONSOLE SIMPLIFIED SCH.

2.2.1 Control Modes

2.2.1.1 Standby

At power on, the console is in the standby mode in azimuth and elevation. In standby the azimuth and elevation brakes are engaged in the pedestal and power is removed from the drive motors.

2.2.1.2 Manual Rate

Minitracker is slewed manually by selecting the manual mode and turning the manual rate knob. This simply provides a positive or negative voltage to the power amp to slew the pedestal in the proper direction. Refer to Figure 9 for a simplified control console schematic. A center tap potentiometer is used to provide the error signal. The potentiometer is spring-loaded such that it returns to the zero drive position when released. Back-to-back zener diodes provide a broader null position to insure smoother small signal slewing. The RC network shown determines the manual mode servo bandwidth.

2.2.1.3 Autotrack

Autotracking is accomplished using a single channel monopulse autotrack system. The RF system including the monopulse converter is described in section 2.3. The autotrack error signal is generated in the monopulse converter in the form of an amplitude modulated error signal. The scan code generator (OSU drawing B95DC06) provides synchronized drive signals to the monopulse converter and the demodulators. The scan code generator (SCG) signals and demodulator signals are shown in Figure 10. The receiver AM signal containing the azimuth and elevation error signals enters both the azimuth and elevation demodulator. (See OSU drawing C95DC05 for a detailed demodulator schematic.) The AM signal enters a pair of FET switches which are driven by the SCG and select either the azimuth or elevation error signal as shown in Figures 9 and 10 at point one. The selected (azimuth or elevation) input enters a preamplifier whose gain may be adjusted by a potentiometer on the front panel. The error signal then enters a transformer which provides an inverted and a non-inverted output. Another pair of FET switches driven by the SCG select the appropriate transformer output to provide the proper drive signal polarity (e.g., positive signal slews tracker up, negative signal slews tracker down). This demodulation technique is illustrated in Figures 9 and 10 at point two. The demodulated signal is then filtered in an active low pass filter whose time constant is set to determine the autotrack servo bandwidth. The filter amplifier may be balanced with a front panel potentiometer adjustment to

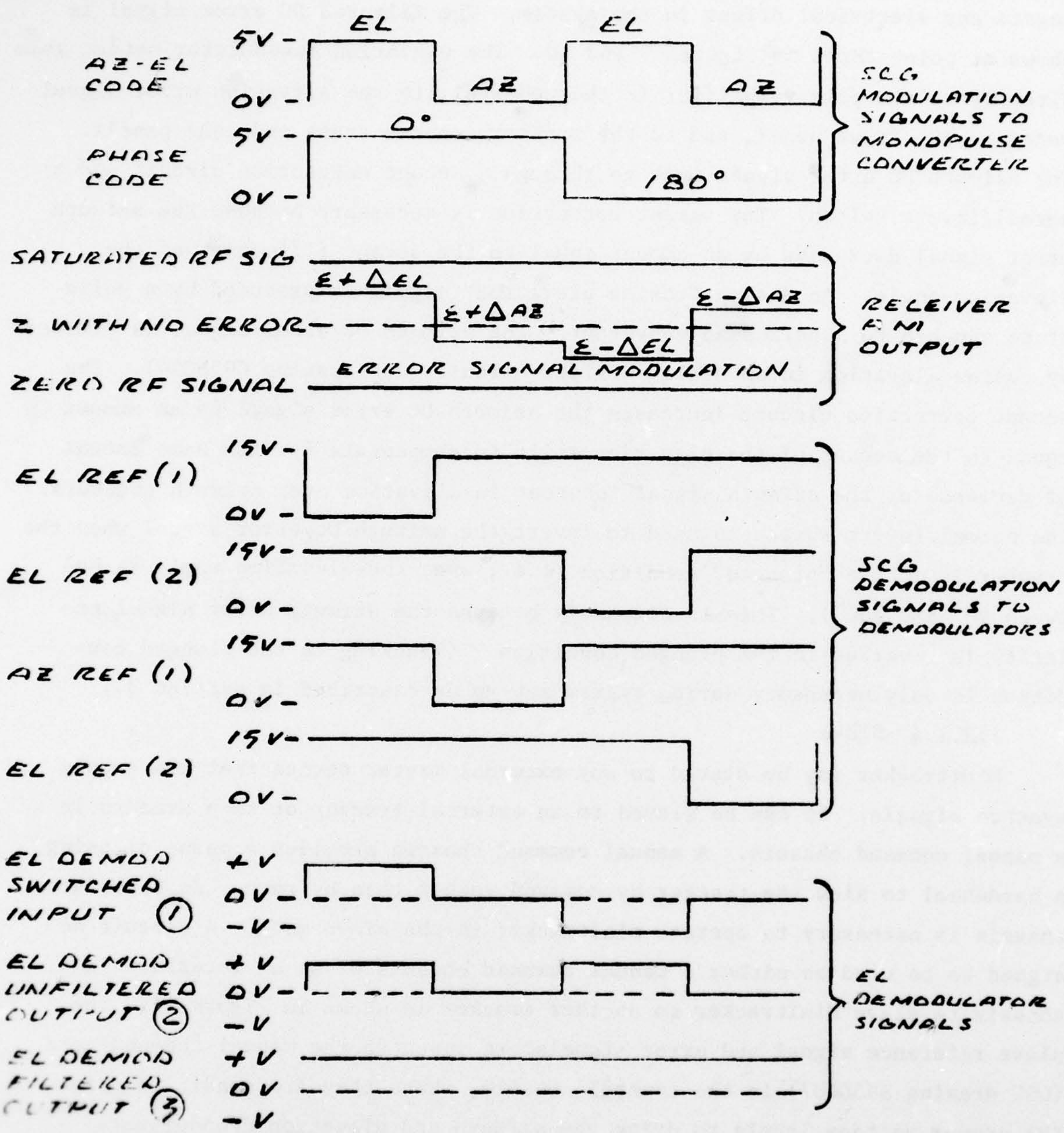


FIG. 10 MINITRACKER IA ERROR SIGNAL MODULATION

negate any electrical offset in the system. The filtered DC error signal is shown at point three in Figures 9 and 10. The elevation demodulator output goes directly to the power amplifier in the pedestal, to the elevation error signal meter on the front panel, and to the monitors on the front and rear panels. The azimuth DC error signal must go through a secant correction circuit and a normal/invert switch. The secant correction is necessary because the azimuth error signal decreases by an amount equal to the secant (1/cosine) of the elevation angle. An analog "cosine elevation" signal is produced by a solid state synchro to sine/cosine converter. The azimuth DC error signal is divided by cosine elevation in an analog divider circuit (OSU drawing C95DC04). The secant correction circuit increases the azimuth DC error signal by an amount equal to the secant of the elevation angle to compensate for the same amount of decrease of the azimuth signal inherent in elevation over azimuth trackers. The normal/invert switch is used to invert the azimuth DC error signal when the tracker is in the "plunged" condition (i.e., when the elevation angle is between 90° and 180°). This is necessary because the azimuth error signal polarity is reversed in the plunged condition. (Tracking in the plunged condition is only necessary during system set-up as described in section 3.)

2.2.1.4 Slave

Minitracker may be slaved to any external master device that can supply synchro signals. It can be slaved to an external tracker or to a synchro in a manual command chassis. A manual command chassis provides a means of using a handwheel to slew the tracker by command rather than by rate. An interface chassis is necessary to operate minitracker in the slave mode. A circuit designed to be used as either a manual command chassis or as an interface chassis to slave Minitracker to another tracker is shown in Figure 11. The slave reference signal and error signals are input to the manual command card (OSU drawing B95DC07) in the control console, where they are conditioned to the proper voltage levels to drive the azimuth and elevation demodulators. The slave reference signal is reduced through a step-down transformer before entering the manual command card. A simplified schematic of the slave circuit in the control console is included in Figure 9. The demodulators demodulate the slave error signals just as they did the autotrack error signals. It should be noted that the R1-R2 115 VAC power phase relationship between the Minitracker and the master device should be identical, or the master device must be able to be switched to the Minitracker R1-R2.

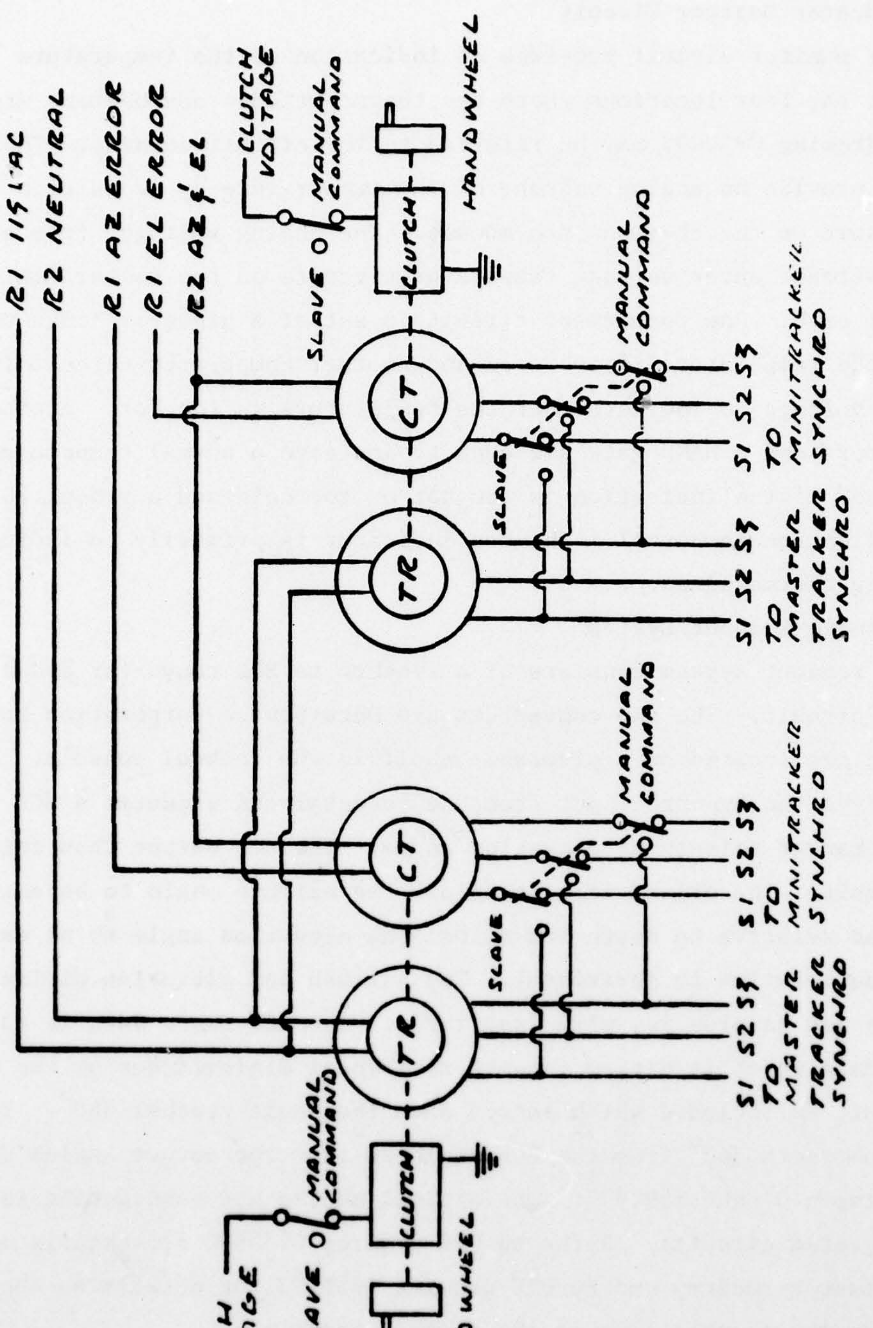


FIG. 11 MINITRACKER IA MANUAL COMMAND SCH.

2.2.1.5 Heater Monitor Circuit

The heater monitor circuit provides an indication of the temperature in the pedestal at the four locations where the thermoswtiches and heaters are located. OSU drawing C95DC03 may be referred to for circuit details. The thermoswitches provide an analog voltage of the temperature by means of a thermistor circuit on the thermoswitch module. The analog voltages from each of the thermoswitches enter voltage comparator circuits on the heater monitor printed circuit card. One comparator circuit is set at a higher voltage to indicate that the temperature is too cold and another comparator circuit is set at a lower voltage to indicate that the temperature is too hot. Another set of comparators and a NAND gate are used to indicate a normal temperature. A red LED is "on" if the indication is too hot or too cold and a green LED is "on" if the indication is normal. The hot indicator is primarily to indicate a malfunctioning thermoswitch.

2.2.1.6 Angle Readout System

The angle readout system consists of a synchro to BCD converter and a digital offset circuit. The two converters are Data Device Corporation Model SR103 units and are located on a pivotable shelf in the control console. The converter receives the synchro input from the pedestal and produces a BCD output of the tracker azimuth or elevation angle. The BCD output then enters the offset circuit. The offset circuit allows the azimuth angle to be easily adjusted to read relative to North and allows the elevation angle to be easily adjusted to read relative to horizontal. The azimuth and elevation digital offset circuits are on plug in, wire wrap cards. The BCD angle data is added to the offset data which is dialed in with thumbwheel digiswitches on the front panel. A circuit is included which senses when the angle reaches 360°. The circuit then subtracts 360° from the BCD angle so that the output angles always remain between 0° and 359.99°. The digital adding and subtracting is done with integrated circuits. Refer to OSU drawing C95DE02 for details of the digital offset circuitry and to OSU drawing C95DE03 for details on the offset circuitry interconnections in the control console.

2.2.1.7 Multicoupler

A four-port S-band multicoupler is provided to allow reception of multilink telemetry signals or to allow the use of back-up receivers. The multicoupler consists of an S-band low noise preamplifier and a four-way power divider. The multicoupler input and outputs are located on the rear panel of the control console.

Table 5. Minitracker IA RF System Specifications

Frequency	2200-2300 MHz
3 db Beamwidth	8^{o}
Acquisition Beamwidth	14^{o}
Sidelobes	10 db down
Sidelobes extend only 1 db above continuous antenna pattern, thereby posing no problem for autotrack acquisition.	
Antenna Gain	26 db
Parabolic Reflector Size	4', two piece assembly
Feed Configuration	Amplitude monopulse, focal point mounted, five element, crossed-dipole.
Reflector Surface Tolerance	1/8" RMS
Feed Support Spars	Quadrapod
Polarization	Right-hand circular
Axial Ratio	2.0 db
Preamplifier Location	Feed mounted to minimize cable losses.
Cross Polarization Ratio	20 db
VSWR	1.5:1
Preamplifier Noise Figure	3.5 db
Characteristic Impedance	50 ohms
RF Calibration	By remotely controlled RF switch in feed.

2.3 RF system

2.3.1 Mechanical

The RF system consists of a four-foot parabolic reflector with an amplitude monopulse autotrack RF feed mounted at the focal point with a quadrapod support. The four foot reflector has a focal length of 18 inches. The RF feed consists of five crossed-dipole antennas behind a fiberglass radome on the front, and a cylindrical enclosure containing the feed electronics on the back part of the feed. Refer to Table 5 for RF system specifications.

2.3.2 Electrical

The RF electrical system consists of 5 cross-dipole antennas, monopulse converter and power supply, RF preamplifier, coaxial relay for RF system calibration, heater, and coaxial cables. Refer to Figure 12 for a simplified schematic of the feed and refer to OSU drawing B95DA01 for further details. All RF interconnections within the feed are made with 0.141" diameter semi-rigid coax. RG-8 cables are used for the received S-band signal and the calibration signal between the feed and the elevation head. RG-58 cables are used in the pedestal between the elevation head and the access door. At this point a 100 foot low loss, superflexible heliax cable is used for the received S-band signal and a 100 foot RG-8 cable is used for the calibration signal.

2.3.2.1 Monopulse Converter

The monopulse converter was developed by OSU, as described in Reference 7. Refer to Figure 13 for a block diagram of the monopulse converter and to Table 6 for converter specifications.

Table 6. Minitracker IA Monopulse Converter Specifications

Frequency	2200-2300 MHz
Construction	Lightweight Stripline
Size	5.52"x6.00"x0.57" (Also requires small ± 12 VDC power supply.)
VSWR, Maximum	1.4:1
Characteristic Impedance	50 ohms
Insertion Loss, Sum Channel	1.0 db
Difference Channel Isolation	42 db
Scanning Frequency	1 KHz
Sum to difference channel phase tracking	$\pm 10^{\circ}$ over the band
RF Connectors	Type SMA
Sum-Difference Channel Combiner	6 db Directional Coupler

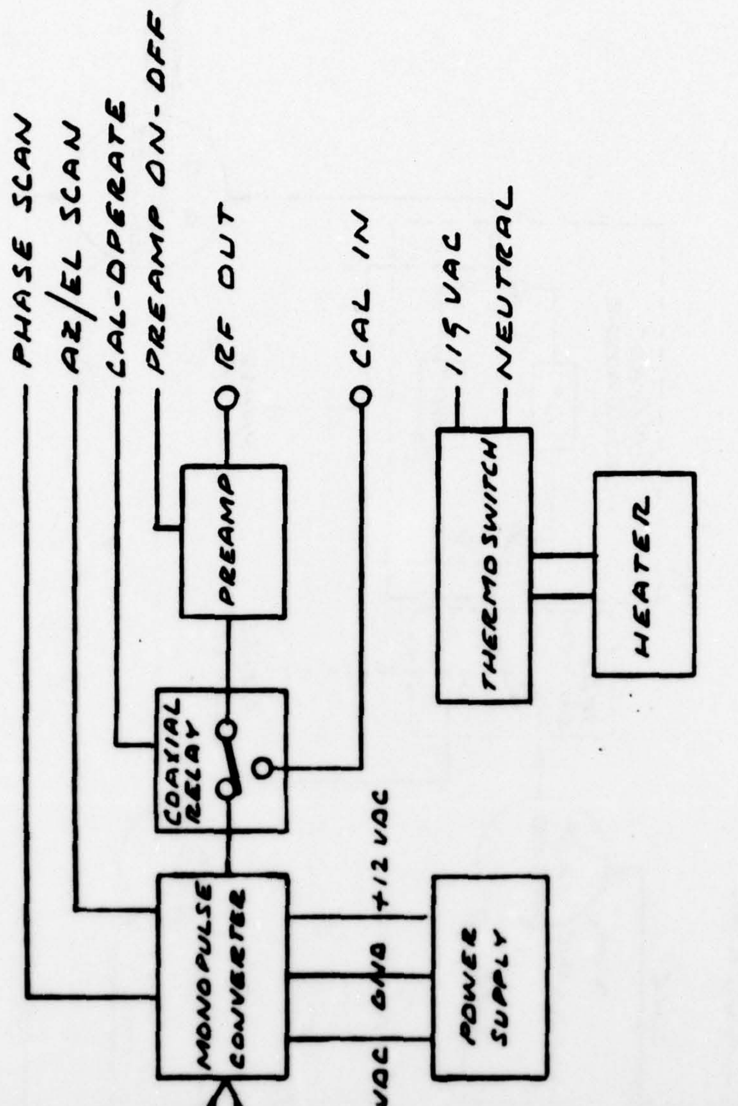


FIG. 12 MINITRACKER IA RF FEED SIMPLIFIED DIA.

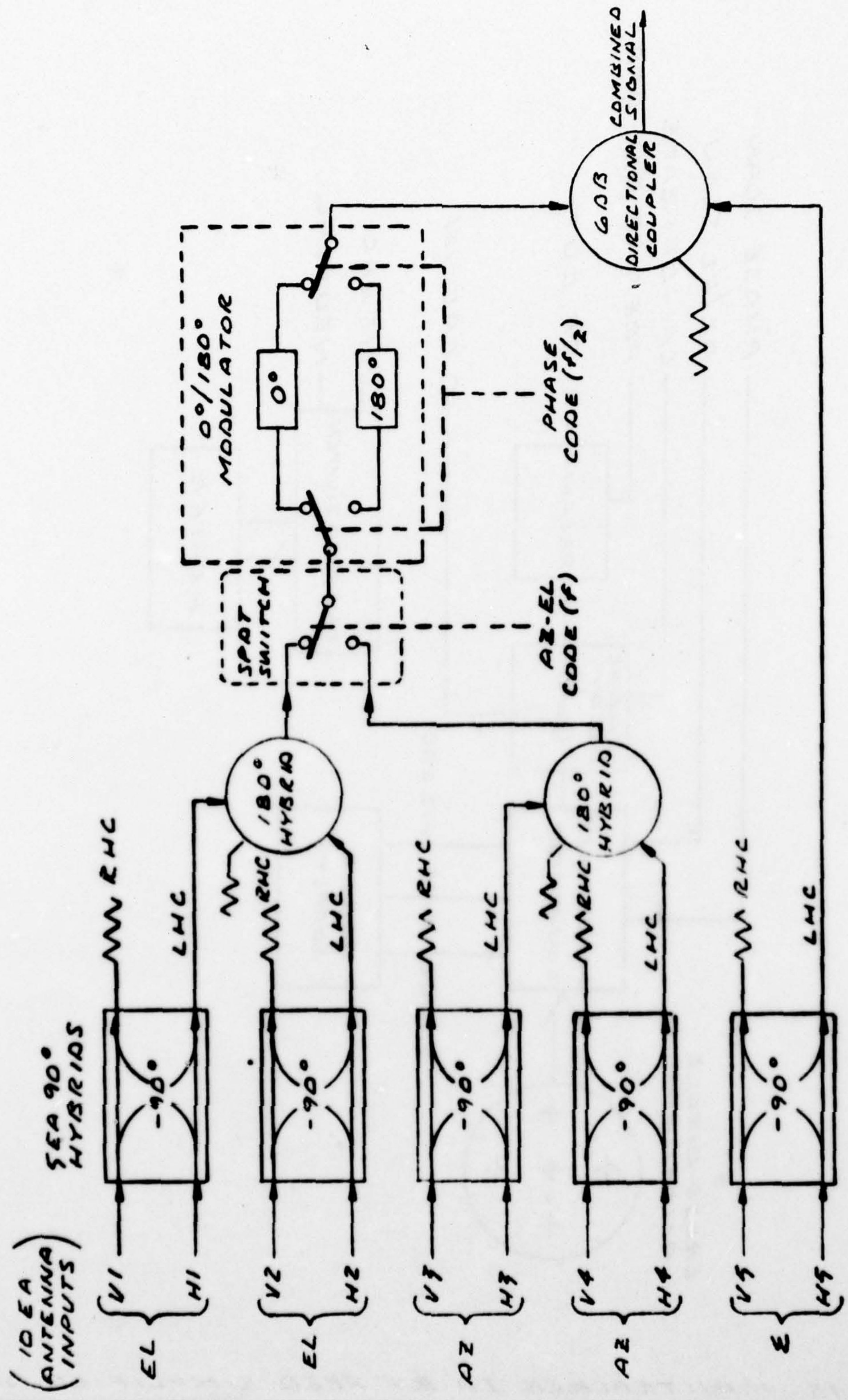


FIG. 17 MINITRACKER IA MONOPULSE CONVERTER

The monopulse converter has ten SMA connector inputs from the five crossed-dipole S-band antennas, one SMA RF output, two SMA connector inputs from the TTL logic, and three solder terminal inputs for $\pm$ 12 VDC and ground. The horizontal (H1 through H5) and vertical (V1 through V5) crossed-dipole antenna inputs of each of the five antennas is converted to left-hand circular (LHC) polarization in five 90° hybrids. (The converter must be connected for LHC polarization for the antenna system to operate in right-hand circular (RHC) polarization, since there is a polarization reversal with the reflection from the parabolodial reflector.) LHC polarization is obtained by connecting the horizontally polarized input such that it feeds directly through the hybrid and connecting the vertically polarized input such that it is delayed by 90° before being summed with the vertically polarized input. The opposite polarization can be obtained by reversing the horizontal and vertical inputs.

The inputs are mounted with two vertical (top and bottom), two horizontal (left and right), and one in the center of the diamond shaped antenna configuration. The central antenna is the primary receiving antenna and is commonly called the Sum (Σ) antenna. The horizontal antenna pair is used to develop a horizontal or azimuth (AZ) autotrack error signal and the vertical antenna pair is used to develop a vertical or elevation (EL) autotrack error signal. The azimuth and elevation pair outputs from the 90° hybrids are subtracted from each other in two 180° hybrids. The outputs from the 180° hybrids are called the AZ difference (ΔAZ) and EL difference (ΔEL) signals. These difference signals are sampled with a PIN diode SPDT switch operated at a frequency of 1000 BPS (f). Then each ΔAZ-ΔEL signal pair sampled by the switch is reversed in phase at a 500 BPS (f/2) rate in the $0^{\circ}/180^{\circ}$ modulator, which also operates using PIN diodes. The error channel is then alternately added to and subtracted from the sum channel due to the phase reversals caused by the phase modulator. This summation is done in an in-phase combiner yielding an autotrack error signal modulated RF signal. The RF signal is detected in a telemetry receiver and the AM output containing the autotrack error signal is fed into the tracker demodulator, where drive signals are generated to drive the antenna to point at the transmitting source and null out the error signals. The autotrack error signal is derived in four steps as follows (Refer to Figures 10 and 13):

(1) The SPDT switch initially selects ΔEL while the $0^{o}/180^{o}$ modulator is in the 0^{o} position. This results in the addition of ΔEL with the sum channel ($\Sigma + \Delta$EL) in the combiner.

(2) The SPDT switch selects ΔAZ while the modulator is still in the 0^{o} position. This results in the addition of ΔAZ with the sum channel ($\Sigma + \Delta$AZ) in the combiner.

(3) The SPDT switch again selects ΔEL while the modulator has switched to the 180^{o} position. This results in the subtraction of ΔEL from the sum channel ($\Sigma - \Delta$EL) in the combiner.

(4) The SPDT switch again selects ΔAZ while the modulator is still in the 180^{o} position. This results in the subtraction of ΔAZ from the sum channel ($\Sigma - \Delta$AZ) in the combiner.

The rocket spin-generated AM interference is eliminated because the error signals are derived by sampling a pair of antennas rather than scanning from one antenna to the other. When the pair of antennas is sampled simultaneously, the amplitude of the RF signal has not had time to change as it would using a consecutive scanning or lobing technique. The monopulse code rate is set at 1000 BPS which is higher than any AM interference. The code could also be made random to further reduce the possibility of any AM interference.

2.3.2.2 RF System Calibration

A means of calibrating the RF system has been provided. RF system calibration not only provides a means of calibrating the system but also provides a means of measuring system threshold to determine if there is a problem with the RF system. When the calibrate mode is selected at the control console, an S-band signal generator signal may be fed into the preamplifier as shown in Figure 12.

3.0 MINITRACKER IA SET-UP PROCEDURES

3.1 Site Selection

Selecting a suitable site for the Minitracker is very important for assuring accurate tracking angle data and proper acquisition and tracking of the target vehicle. The following are considerations to be made in selecting a site for the tracker:

1. Level ground for pedestal.
2. Unobstructed view in direction of target vehicle trajectory.
3. Unobstructed view in direction of balloonsonde trajectory for boresight telescope alignment. (This procedure is described in section 3.8.)
4. Unobstructed view in direction of a boresight source.
5. Pedestal limited to being located only 100 feet from tracker controls by cable length.

3.2 Assembly

The Minitracker normally requires two people for assembly, although one person can assemble it with some difficulty. Assembly requires the use of only a 9/16" wrench and a screwdriver. Minitracker is packed in plastic cases as follows:

1. Legs, RF feed, feed support arms, leg mounting ring, foot pads.
2. Riser.
3. Elevation head.
4. Dish.
5. Cables.
6. Control console.
7. Receiver.

The Minitracker pedestal is assembled as follows: (Refer to Figure 3.):

1. Carry boxes 1 through 5 to the selected pedestal location.
2. Open box 1 and remove contents.
3. Install foot pads on tripod legs.
4. Mount tripod legs to leg mounting ring.
5. Locate tripod legs at pedestal site.
6. Remove riser from box 2.
7. Install riser on top of leg mounting ring.

This is facilitated by having one person slightly lift the leg mounting

ring with one hand while the riser is being installed. This spreads the leg mounting brackets so the riser can fit between them. Another way is to set the leg mounting ring on a box to spread the leg mounting brackets and then remove the box after installing the riser. The riser must be oriented so that an azimuth limit will not be hit while tracking (i.e., $\pm 180^{\circ}$ slew, with respect to target trajectory).

8. Remove access door from riser (requires a screwdriver).
9. Remove elevation head from box 3.
10. Install elevation head on riser. The elevation control cable and two RF cables from the elevation head must be fed through the riser and connected to the appropriately marked locations on the back of the access door. Note that the elevation head is keyed so that it mounts in the proper direction on the riser. (Before repacking, the elevation axis should be pointed in the vertical direction so the elevation head will fit into its case.)
11. Replace access door on riser.
12. Remove the dish from box 4.
13. Bolt the two dish halves together.
14. Mount the feed support arms and feed from box 1 to the dish.
15. Remove the cables from box 5.
16. Connect the feed control cable and two RG-8 cables to the feed.
17. Mount the dish assembly to the elevation head.
18. Connect the feed control cable and two RG-8 cables to the elevation head.
19. Connect the control cable, power cable, S-band superflexible heliax cable, and RG-8 calibration cable to the access door. (These cables are all 100 feet long.)
20. Route the 100 foot cables to the tracker control console location.
21. Remove the tracker control console and S-band receiver from their boxes and install them.
22. Connect the tracker control and power cables to the back of the control console.
23. Connect the S-band superflexible cable to the multicoupler input.

24. Connect the RG-8 calibration cable to a signal generator.

25. Connect a coaxial cable between the multicoupler output and the receiver input.

26. Connect an RG-58 cable between the receiver AM output and the tracker console AM input.

27. Connect an RG-58 cable between the receiver AGC output and the tracker console AGC input.

28. Connect the AC cords into any suitable AC outlet. Ten amperes is more than adequate.

29. If windy weather is anticipated, place weights on the tripod feet or anchor the feet to the ground with ground screws.

3.3 Tracker Levelling

The tracker, when used to determine rocket trajectories, must be levelled to an accuracy approaching a surveyor's transit or else there will be errors in the trajectory data. Minitracker needs to be levelled to within $.03^{\circ}$. A circular bubble level of this accuracy is provided in the elevation head. It is visible through a plexiglass window on the top of the elevation head. The tracker is levelled as follows:

1. Release elevation brake and move dish to a horizontal position to gain access to the bubble level.
2. Engage elevation brake.
3. Adjust screw jacks to center bubble.
4. Lock screw jacks with lock nut.

The circular bubble level is preset so that it will normally not need to be adjusted. However, its adjustment should be checked periodically as follows:

1. Level pedestal as described previously.
2. Release azimuth brake.
3. Slew pedestal 180° in azimuth by hand while watching the level, being careful not to slew the tracker past an azimuth limit.
4. If the bubble remained within the circle on the level; the level is properly adjusted. If the bubble moved out of the circle, the level needs to be adjusted as follows:
   a. Adjust the screw jacks to center the bubble.
   b. Rotate the pedestal in azimuth while watching the bubble and stop the pedestal at the point of maximum error.

c. Remove the plexiglass window.

d. Adjust the level adjustment screws to take out half the observed error.

e. Adjust the screw jacks to center the bubble.

f. Rotate the tracker 180°.

g. Repeat steps d through f until the bubble remains at the center.

h. Rotate the pedestal while watching the bubble and stop at the point of maximum error if any. If the bubble remains in the circle, the level is properly adjusted; if not, repeat steps d through f until the bubble remains in the level circle.

i. Engage azimuth brake.

3.4 Boresight Source Set-Up

A boresight source must be set up to properly test and adjust the Minitracker control console electronics. The boresight source consists of an S-band source of approximately ten milliwatts output and an S-band antenna. The location for the boresight antenna must be very carefully selected to assure proper tracker set-up. The following conditions must be met as closely as possible to assure an accurate tracker set-up:

1. Unobstructed line of site between tracker and source.
2. Source elevated to 10° above tracker.
3. Sturdy mounting for boresight antenna (e.g., stable tower). (Movement of the boresight antenna will cause movement by the Minitracker when tracking the boresight.)
4. No moveable or moving objects such as trees, other antennas, or automobiles should be within the field of view of the Minitracker antenna.
5. Boresight should be several hundred feet away from Minitracker.

3.5 Electronics Set-Up

The following procedures describe how to check and set up the Minitracker electonics:

1. Energize the control console and verify that it is in the standby mode.
2. Test manual rate operation by selecting manual mode and

AD-A062 472 OKLAHOMA STATE UNIV STILLWATER ELECTRONICS LAB F/G 4/1
ROCKET INSTRUMENTATION SUPPORT SERVICES.(U)
AUG 78 R F BUCK, R M FIKE, C M GWINN F19628-75-C-0084
UNCLASSIFIED AFGL-TR-78-0207 NL

3 OF 3
AD
A062472

END
DATE
FILMED
3-79
DDC

slewing the tracker. If both limit lights for either azimuth or elevation are on, the brake release switch on the pedestal is in the released position and must be placed in the engage position before the tracker will slew. If all the limit lights are on, the brakes are both released or the disable switch on the pedestal is in the disable mode. The brake switches must be in the engaged position and the enable-disable switch in the enable position for the tracker to operate. These switches are located on the pedestal access door.

3. Check the operation of the limit circuitry by slewing the tracker into the limits and verifying that the tracker stops and the appropriate limit lights come on.

4. Test the preamplifier on/off switch by verifying that the signal strength meter level increases when the preamplifier is on.

5. With a signal generator tuned to the receiver frequency, select the calibration mode and verify the reception of the calibration signal. Place console back in operate mode.

6. Check autotrack operation by autotracking the boresight source. Slew off the source a few degrees and verify autotrack acquisition.

7. Balance azimuth and elevation demodulators as follows:

a. Allow a 15 minute warm-up after turn on.

b. Turn all RF sources off.

c. Select azimuth autotrack mode.

d. Adjust azimuth balance pot on the front panel until there is no motion of the pedestal as observed on the angle readouts. (Balanced on receiver noise.)

e. Select azimuth standby mode.

f. Repeat steps c. through d. for elevation axis.

8. Set azimuth and elevation demodulation gain as follows:

a. Autotrack boresight source.

b. Put in standby mode.

c. Put tracker in manual modes and slew tracker off boresight 1.00° in azimuth. Return to standby mode.

d. Adjust the azimuth gain pot on the front panel such that the azimuth error signal meter reads 1.00°. Press autotrack to null error signal and return to standby.

e. Repeat steps a through d for the elevation axis.

3.6 RF System Calibration

A recorded and real time signal strength calibration should be made for a threshold check and to provide a means for post mission signal strength analysis. The signal loss of the RG-8 calibration cable must be known in order to calibrate the system. The RF system is calibrated as follows:

1. Select the calibration mode.
2. Select the preamplifier on mode.
3. With the signal generator off or at a zero signal level setting, zero the signal strength meter on the receiver.
4. Tune the signal generator to the receiver frequency.
5. If possible, set modulation of the signal generator to that expected during the mission.
6. Set the generator at an effective level of -110 dbm. For example, the actual setting would be -87.7 dbm with a calibration cable loss of 22.3 dbm.
7. Record the signal strength in 10 dbm steps to -50 dbm effective (or -27.7 dbm actual, using the above example).

The system threshold can be checked by observing the receiver video output at low signal levels to determine if the signal-to-noise ratio appears normal.

3.7 Boresight Correction

A test must be made to determine if the tracker RF axis is offset from the mechanical axis. This is necessary because the tracker points the antenna along the RF axis, but the azimuth-elevation readout measures angles relative to the mechanical axis. The elevation offset may be removed by adjusting the elevation display digital offset, but the azimuth offset is a complex function of the elevation angle as derived in section 5.0 of Appendix A of Reference 3. The boresight correction is necessary only if elevation tracking angles above 70° are anticipated. The boresight correcton is made as follows:

1. Autotrack a boresight signal and record the azimuth and elevation angles.

2. Rotate the tracker 180° in azimuth and elevate the dish to a reading of 180° minus the original elevation reading.

3. Switch the normal/invert switch to the invert position.

4. Again autotrack the boresight source and record the azimuth and elevation readings. This is the plunge azimuth and plunge elevation reading.

5. The azimuth boresight error is calculated as follows:

$$\text{Azimuth Correction} = \frac{(\text{Plunge AZ} - \text{Normal AZ}) \pm 180^\circ}{2}$$

(Sign of 180° opposite that of (Plunge Az - Normal Az))

6. If the boresight error is greater than .03°, the feed support must be adjusted in the proper direction to align the RF axis with the mechanical axis. After adjustment, steps 1 through 5 must be repeated until the azimuth boresight error is within .03°. The azimuth offset may also be allowed for mathematically in data reduction using the following equation:

$$\text{Corrected Azimuth} = \text{Az} + \text{Az correction}/\text{Cos El}$$

7. The elevation boresight error is calculated as follows:

$$\text{Elevation Correction} = \frac{180^\circ - (\text{Plunge El} + \text{Normal El})}{2}$$

8. The elevation boresight error may be adjusted to zero with the elevation readout digital offset digiswitches. The elevation angle is now defined at 0.00° when the RF axis is horizontal to the Earth's surface.

3.8 Angle Readout Set-Up

The azimuth-elevation readout must be set up very accurately to assure accurate vehicle trajectory data. The readouts are normally set up such that 000.00° in azimuth corresponds to true North and 000.00° in elevation corresponds to horizontal to the Earth's surface. The elevation readout is set up as described in section 3.7 but the following procedures provide a secondary check of the elevation set-up as well as the primary azimuth readout set-up. The set-up procedure involves aligning the optical axis of a boresight telescope with the RF-axis of the tracker and then centering a celestial body (such as Polaris) with a known location in the telescope cross-hairs.

The boresight telescope is aligned by tracking an S-band balloonsonde and centering the balloonsonde in the telescope cross hairs. The exact procedure for setting up the boresight telescope is as follows:

1. Level the tracker, set up the tracking electronics, and make the appropriate boresight corrections as described in sections 3.3, 3.5, and 3.7.

2. Install the telescope.

3. Prepare a balloon with at least 200 grams of lift, an OSU S-band source, and two 9 volt transistor batteries.

4. Attach the sonde at least 10 feet below the balloon and attach a small weight at least 10 feet below the sonde to damp out swinging of the sonde.

5. Allow the tracker electronics to warm up for at least 15 minutes.

6. Launch the balloonsonde when the winds won't carry the sonde behind obstructions to the tracker's line of sight.

7. Acquire and autotrack the balloonsonde. See section 4.2 for acquisition information. After the balloonsonde has drifted approximately one mile away (far enough to reduce parallax to an acceptable level) and is at least 10° above the horizon, adjust the scope to center the sonde (just below the balloon) in the cross-hairs. The scope should initially be adjusted to 3 power. The coarse adjustment is made using the scope mount. After the sonde is centered in the telescope, adjust the telescope to 9 power. The scope can be adjusted to center the sonde in the cross-hairs using the fine adjustments on the scope itself.

The exact location of a celestial body such as Polaris must be known. This position data is used as a reference to set the digiswitches on the angle readouts. If it is necessary to calculate the position of the celestial body, refer to Appendix I of Appendix A of Reference 3. It is preferable to use Polaris as the reference because its position is easier to calculate and its position doesn't change very much. The azimuth and elevation angle of the reference must be known to within $.01^{\circ}$ and the time of observation must also be known. If Polaris is used as a reference, the time of observation can be as much as ten seconds off. The following procedure should be followed to adjust the azimuth angle readout:

1. Put Minitracker in the standby mode.

2. Put the azimuth and elevation brake release switches in the release mode. (They are located on the pedestal access door.)

3. Move the dish by hand until the target can be sighted over the telescope.

4. Adjust the scope to 3 power and move the dish by hand until the target is centered in the scope.

5. Adjust the scope to 9 power and move the dish by hand until the target is again centered in the scope.

6. Make sure the target is centered in the cross-hairs at the observation time.

7. Put the azimuth and elevation release switches in the engage mode.

8. Adjust the azimuth digiswitch to make the azimuth display indicate the calculated celestial body azimuth angle.

9. The elevation reading should be within $.05^{\circ}$ of the calculated celestial body elevation angle due to the adjustments made from section 3.7.

4.0 MINITRACKER IA OPERATION

Just prior to tracking a vehicle during a mission, check the tracker levelling and verify autotrack operation by tracking the boresight source. The rest of this section deals with target acquisition which is the most difficult aspect of tracker operation.

4.1 Acquisition From Liftoff

If there is a clear line of sight between the tracker and the target vehicle, the vehicle may be tracked from liftoff. Of course if the vehicle is a rocket, the tracker must be far enough away from the launch site so that its slew rate will not be exceeded during liftoff. The RF signal from the vehicle must first be acquired and autotrack begun while the vehicle is still at the launch site. Acquisition is accomplished by pointing the tracker dish in the manual mode to maximize the RF signal strength and then switching to the autotrack mode. The tracker should automatically track the vehicle at liftoff and throughout the rest of the flight. If the RF signal strength indicates the receiver is saturated, the preamplifier should be turned off or difficulty may be experienced in autotracking. After the signal strength has decreased, the

preamplifier may be switched on. If the tracker loses track at liftoff, it must be switched to manual mode and pointed again to maximize the RF signal strength and then switched back to autotrack. If the target is at a high elevation angle, it is best to maximize the RF signal by slewing the tracker in azimuth first and then in elevation. This is because at high elevation angles the azimuth acquisition beamwidth is very large and so the azimuth pointing direction is less critical. The tracker must be pointed at the vehicle within its acquisition beamwidth, which is 14° for Minitracker (i.e., the tracker must be pointed to within $\pm 7^{\circ}$ of the vehicle). The azimuth acquisition beamwidth increases as the secant of the elevation angle.

4.2 Acquisition After Liftoff

If Minitracker is to be used to track rockets and is located so close to the launcher that it can't slew fast enough to track the rockets from liftoff, then the rockets must be acquired in the autotrack mode after liftoff. In this case the tracker dish is pre-positioned at the nominal azimuth and elevation launch angles and switched to autotrack approximately 10 seconds after liftoff when the rocket has entered the acquisition beamwidth of the tracker. It should be noted that adequate RF signal will be received during the period of time before autotrack acquisition. If the receiver is saturated, the preamplifier should be turned off until the signal strength has decreased. The problem in acquisition is to avoid locking on and tracking a sidelobe. If acquisition is made on a sidelobe, it is obvious because the track is very rough and the RF signal strength is relatively low. If acquisition is made on a sidelobe, switch to manual mode and slew the tracker to maximize the RF signal strength and then switch back to autotrack. It is best to first point the dish at the launch azimuth angle and then slew in elevation to maximize the RF signal. This is due to the increased azimuth acquisition beamwidth size, as explained in section 4.1. Once proper autotrack has been achieved, the tracker should maintain autotrack throughout the rest of the flight.

If autotrack acquisition is to be made on an airborne target such as a balloonsonde, the following method should be used: First slew the tracker manually in azimuth and elevation to point the dish in the general direction of the target. Next, maximize the RF signal strength by slewing the tracker in azimuth. Then, maximize the signal strength by slewing the tracker in elevation and put the tracker in the autotrack mode. The tracker should acquire the target and maintain autotrack.

LIST OF REFERENCE

1. Staff Authors; Research Rocket Instrumentation. (Final Report to F19628-72-C-0224). Research Foundation, Oklahoma State University, Stillwater, Oklahoma. (AFCRL-70-0322; April 1970).

2. Buck, Richard F. (with A. D. Costner, C. M. Gwinn, R. M. Fike, D. R. Lynch, P. R. Park, J. R. Slaughter, & J. B. Zinn): Engineering Support Services, Instrumentation for Aerospace Research Program. (Final Report to F19628-70-C-0147). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-72-0447; 15 July 1972).

3. Buck, Richard F. (with R. M. Fike and C. M. Gwinn): Instrumentation for Research Rockets. (Final Report to F19628-72-C-0139). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-TR-7-0216; 30 April 1975).

4. Buck, Richard F. (with R. M. Fike): Support Services for I.R. Rocket Payloads. (Final Report to F19628-72-C-0172). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFGL-TR-76-0031; March 1976).

5. Fike, R. Michael: Mobile S-band Trajectory Determination and Telemetry Receiving Systems. (Scientific Report No. 2 to F19628-72-C-0139). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFCRL-TR-73-0716; November 1973).

6. Fike. R. M.: Trajectory Determination and Telemetry Receiving System Evaluation. (Scientific Report No. 2 to F19628-75-C-0084). Electronics Laboratory-DETA, Oklahoma State University, Stillwater, Oklahoma (AFGL-TR-76-0276; November 1976).

7. Fike, R. M.: Single Channel Monopulse Converter. (Scientific Report No. 1 to F19628-75-C-0084). Research Foundation, Oklahoma State University, Stillwater, Oklahoma (AFGL-TR-76-0085; 1 March 1976).